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# LUMBER VOLUME YIELD FROM BLACK WALNUT (*JUGLANS NIGRA* L.) LOGS

**Josip Ištvanić, Krešimir Greger, Ivana Perić[1], Marko Pečenec[2], Alan Antonović[1]**

[1]*Wood Technology Department, Faculty of Forestry, University of Zagreb, Republic of Croatia*
*e-mail: jistvanic@sumfak.hr; kgreger@sumfak.hr; iperic@sumfak.h; aantonovic@sumfak.hr;*
[2]*Joinery and sawmill Antun Pečenec Ltd.*
*e-mail: pecenec@pecenec.hr*

## ABSTRACT

This paper experimentally and theoretically researches the performance indicators of sawmill processing of black walnut (*Juglans nigra* L.) logs in sawn boards. The research covered the veneer and sawmilling logs of the black walnut classified according to the Croatian standards. For the requirements of the experiment, the logs at the sawmill were classified into four qualitative classes: 1$^{st}$ class veneer logs, 2$^{nd}$ class veneer logs, 1$^{st}$ class sawmilling logs and 2$^{nd}$ class sawmilling logs. Logs were sawn up in the 30 and 50 mm nominal thickness of sawn boards. A mechanized line based on vertical log band saw with hydraulic carriage was used for primary sawing up. The 1$^{st}$ class veneer logs proved to produce the best lumber volume yield results. The 2$^{nd}$ class sawmilling logs proved to produce the worst volume yield results.

**Key words:** Black walnut (*Juglans nigra L.*), veneer log, sawmilling log, sawmilling, sawn board, lumber volume yield

## 1. INTRODUCTION

Black walnut (*Juglans nigra* L.) is a species of the eastern part of North America, which was introduced in Europe in 1629 (Jovanović, 1985). It was initially grown as a park type, and later to the present day, it is increasingly used as an economic species. Black walnut is poorly represented in wood species in Croatia. In the total wood stock in the Republic of Croatia, it is represented only by 0.1%. Black walnut comes exclusively as part of a forest community and very rarely can it be found as part of an orchard or courtyard. The tradition of cultivating a black walnut culture in a community with one or more autochthonous or alohton tree species has been more than a hundred years old in the area of Eastern Slavonia. In the area that is being managed by the Croatian Forests, the site of the forest Vinkovci, facility Vukovar and Ilok Forestry, the seed was brought in 1899 (Herman, 1971). The reason for introduction of black walnut in the forest was drying oak (Sevnik, 1926). The cultures of black walnuts of the Vukovar region are developed in the community of the oak-tree forest and the common hornbeam (*Carpinus betulus* L.) with turkey oak (*Quercus cerris* L.) (Rauš, 1969), which represents a transitional forest-based community. Matić & Prpić (1983) state that black walnuts are suitable for afforestation in protected habitats of oak trees where they will produce valuable wood masses.

Due to the poor presence in forests as well as other fruit trees, the black walnut is processed in small quantities in Croatian sawmills and veneer factories. The black walnut final industrial processing in Croatia almost does not exist, but it serves as a raw material for some foreign industries in the production of exclusive furniture and other luxurious items. Accordingly, its processing procedures are less explored. But on the other hand, as a very appreciated type of wood, it also gives a certain interest in a number of unknowns in this case, sawmilling processing.

Given that in this part of the research we will deal with walnuts, some research results related to sawmill processing of this species of wood will be stated.

Dunmire et al. (1972) found that a volume yield of black walnut low quality and small-sized round wood used to produce the sawmill products is in the range from 26 to 47%.

Rosen et al. (1980) explored the utilization in sawmill processing of short low-quality sawmill raw material of black walnut. Primary orientated cutting is carried out by live sawing technique. Sawn boards were dried to 8% moisture content, reduced to a final thickness, and classified into three classes of quality. Based on these findings, the authors have drawn diagrams predicting utilization of such logs due to their length and thickness of the sawn board to be sawn from them. It was also found that the volume yield, and therefore the financial effect when processing such sawmill raw material, is by up to 15% lower, as opposed to the standard sawmill raw materials processing.

Stewart et al. (1982) analysed the economic acceptability of processing of thin and short low-quality round wood with a diameter of 15 cm and more, and length of 0.6 m and more, on three hypothetical sawmills. The cost-effectiveness of investing in facilities that worked on such raw material was also considered. The analysis was based on observations at several existing sawmills. Each hypothetical sawmill was equipped with conventional machines, or with innovative machines. Basic materials were unedged sawn boards obtained from thin big tooth aspen (*Populus grandidentata* Michx.), black walnut and black cherry (*Prunus serotina* L.) round wood. The results show that the most economically favourable is processing of black walnut, followed by black cherry and at the end was the big tooth aspen. In general, it was found that the larger sawmill and the more valuable wood species, the greater the economic acceptability of processing. Comparing the conventional and innovative type of processing, given the energy costs and actual cost, innovative methods have demonstrated better results.

Huber et al. (1983) continued with similar studies. This time they studied the actual cost of processing of thin and short low-quality sawmill raw material of poplar (*Populus* spp.), black cherry, silver maple (*Acer saccharinum* L.), American aspen (*Populus tremuloides* Michx.) and black walnut. The final products were elements for furniture production. This research was carried out on a hypothetical example using a computer program, and the points of equalizing costs were analysed. Point of equalizing was determined so that the amount of small diameter round wood was increased until the number of elements obtained after processing was not equal to that obtained from the standard round wood. The black walnut showed the highest point of equalizing costs; primarily because of the high cost of standard sawmill raw materials. The conclusion was that thin and short low-quality sawmill raw material from valuable wood species has a wide area for competition with the classic sawmill raw material.

An interesting study was conducted by Phelps and Chen (1989). They studied the properties of logs and wood of plantation grown and naturally grown black walnut. The quality of logs and sawn boards, wood shrinkage, wood defects, the percentage of core, increment and specific density were compared. It was shown that sawn boards of naturally grown black walnut are a class better than sawn boards of plantation grown black walnut. Logs made from plantation trees had more knots, because of dead branches, which could have been avoided if the trees on plantation were let to grow for about eight years, because they would then be about the same age as the trees that have grown naturally. This would increase the quality of sawn boards from marginal parts of the logs from plantation trees. The results obtained indicate that to get higher quality logs in plantation cultivation the trees would have to grow closer together the first 10 to 15 years, and then thinning was done. Logs from the plantation had 20% less core than those naturally grown, and 40% faster growth. Finally, the researchers found that the plantation grown trees were younger and shorter, with a faster growth rate and a lower core percentage than naturally grown trees. Wood from plantation trees was of lower quality than from naturally grown ones, because it had more knots. All the sawn boards dried well, shrinkage was within the permitted limits and drying did not change the quality of wood. No difference in specific density between plantation and natural trees was noticed, but it clearly changed from the core to the bark. They found that the properties of wood were affected by the age, genotype and the environment, but it is not known to what extent.

Prka et al. (2001) and Ištvanić at al. (2011) have studied the volume yield of logs of common walnut (*Juglans regia* L.) at certain stages of sawmill processing. The results have shown that the volume yield of class I. logs when making sawn boards is around 72%, and for the class II. 69%.

Volume yield of logs in the form of dimension stocks and raw parquet staves amounted for class I. about 35%, and for the class II. about 26%. Volume yield and the financial returns of sawing these wood species is very similar to sawing pedunculate oak (*Quercus robur* L.), sessile oak (*Quercus petraea* Matt.) and common European beech (*Fagus sylvatica* L.). Volume yield in parquet production is closely correlated to volume yield in primary and secondary sawmills. Therefore, the volume of finished two-ply parquet, as the final product, increased in the plant where this research was conducted and also increased in the processing of higher-quality class sawlogs.

Ištvanić et al. (2016) have studied the volume yield of small-sized round wood of common walnut in Croatia. The results have shown that the volume yield of round wood during its processing into sawn boards ranged from 54.34% to 88.83%. Volume yield of round wood during its processing into dimension stock and raw parquet staves ranged from 17.01% to 52.14%.

Rabadjiski et al. (2015) researched the impact of quality, diameter and length of common walnut logs on volume yield in the production of unedged, halfedged and edged boards. They were logs from 36 to 55 cm diameter. Depending on their length, the logs were distributed into one of the four groups: 1.5 m, 2.0 m, 2.5 m and 3.0 m. These results showed volume yield of round wood was 61.24 to 68.10 %. Relation between volume yield and group of length in walnut logs is determined using function: $Y = -8.08\,x^2 + 38.68x + 21.15$ with coefficient on correlation 0.973.

## 2. AIM OF RESEARCH

In Croatian forests, fruit trees are represented by only 0.5%. The most important species are: common walnut, wild cherry (*Prunus avium* L.), sweet chestnut (*Castanea sativa* Mill.), black walnut, olive (*Olea europea* L.), wild apple (*Malus communis* L.), wild pear (*Pyrus pyraster* L.), mountain ash (*Sorbus aucuparia* L.), service tree (*Sorbus domestica* L.) etc. It should be mentioned that although very attractive and somewhat unique, the demand for these species of wood depends on the trends in design and design of furniture.

Most of the black walnut logs, whether of logs for processing in cut veneer or sawmill processing, end up in Western European countries, and most often in Italy. Similar destiny is also made with sawmill products of black walnuts, either in the form of sawn boards or wooden elements. The final product of black walnut in Croatia almost does not exist, possibly as a semi-finished product in the form of mass glued wooden boards and prefabricated parquet.

Because of its high value, as well as a small number of articles (especially from the point of view of sawmill processing), the black walnut in Croatia is a very interesting species for research. Therefore, the aim of this research is to experimentally and theoretically investigate one of the indicators of the success of sawmill processing of black walnut logs, which is the volume yield in the processing of logs in sawn boards

## 3. OBJECTS AND METHODS OF RESEARCH

In the youth, black walnut is a particularly beautiful tree because of its pyramidal crowns and large leaflets, and as an adult tree planted in parks and other urban forestry areas, it gives a rich shade. They grow over 30 m and sometimes up to 50 m and reach a 2 (3) m diameter chest. Broad branches are crowned, so the trunk does not reach the top of the trellis. An old tree with a crowned crown, especially if grown apart, may have thick branches, 10 m or more. The stump is high, dark. The early young tree is grayish-gray to grayish-brown and smooth. The rampage begins in the third or fourth year. In old trees, the tree is deeply oblong and dark brown to grayish. The leaves are aromatic when they last, (4) 6 to 12 (19) cm long, (1.5) and 2 to 5 (8) cm wide, eyelid, long and pointed to the tip. The fruit is rounded or slightly melted, 3.5 to 6 cm in diameter and aromatic.

Sawmill and veneer logs are produced from the technical round of black walnuts. It is also possible to technically use the underground part (stump and root). Most commonly, black walnut trees are treated like other types of sawing and cutting on a veneer knife. Sawn timber and veneers are further used to produce every kind and finest exclusive furniture, interior decorations, special products for various purposes and especially for making hunting rifles gunstock.

The black walnut is very valuable, colored heartwood and diffuse-porous wood species. The wood has a remarkable glossy texture and firmness and is very durable. It is resistant to the action of various fungi and insects. In anatomical terms, it resembles common walnut. Fresh wood smells like asphalt.

The color of black walnut wood is very recognizable from its chocolate to purple-brown color of the heartwood and whitish to the yellow, gray and grayish and light-colored sapwood. The color on the fresh cross section is changed by the drying and the flow of time from the turquoise green to the bluish that loses itself and passes into a characteristic chocolate-brown color. By thermal processing, weaving, it comes to equalizing the color of the obstinate and unresponsive part.

Black Walnut wood is easily handled by all tools and machines. It is very easy to coat with waxes and easily polishes. The adhesion also suits well, as well as the fastening of bolts and nails, which hold great.

### 3.1. Log selection and measurement

The study is based on Black walnut trees harvested from Croatia the site of the forest Vukovar, facility Jelaš. The logs were graded according to Croatian norm regulations HRN-D.B4.028 and HRN-EN-1315-1. A total of 137 Black walnut logs were separated into four grades. The 1st grade veneer logs consisted of 7 logs. The 2nd grade veneer logs consisted of 49 logs. The 1st grade saw logs consisted of 54 logs. The 2nd grade saw logs consisted of 27 logs. The minimum log length was 1.6 meter, but they could also be longer. The minimum mid-diameter was 19 cm, but they could also be greater (figure 1, 2 and 3).

All sample logs were measured without bark by length and mid-diameter. Descriptive statistics were executed for all analysed variables: Average, standard deviation, minimum, median, and maximum. For log mid-diameter and length, the significant, difference in medium values and group of data were verified. These parameters enabled the analysis of raw material structure for experimental sawing. Individual log volume was calculated according to equation (1). For statistical data analysis on the volume yield Microsoft Office Excel was used.

$$V_{\log} = \frac{D_{\mathrm{mid}}^{2} \cdot \circledR}{4} \cdot L_{\log} \qquad (1)$$

where: $V_{\log}$ – log volume, $m^3$; $D_{\mathrm{mid}}$ – mid diameter of the log, m; $L_{\log}$ – log length, m.

### 3.2. Processing logs in the primary sawmill

The primary sawmill, where this study was conducted, was located in Kapela Podravska, Croatia. Mill equipment included a 1400 mm log band saw headrig, with automatic hidraulic-operated carriage, an edger and a cross-cut circular saw.

Logs were processed individually on the log band saw using the live sawing method. All sawn boards produced in this research were intended for further processing at the same facility, and therefore were not separated according to quality. Boards were produced with a nominal thickness of 30 and 50 mm and with 22 % moisture content (figure 1.). Taking shrinkage into account, the target saw thickness was 32 and 55 mm. Since the boards were not edged, width oversize was not calculated.

The oversize for the sawn board nominal length was at least 2 cm. The 30 mm boards were sawn from the outer portion or jacket of the log. Thicker boards were sawn from the center part of the log. All sawn boards produced from the sample logs were measured for thickness, width, and length according to EN 1309-1 and EN 1313-2 and sawn board volume was calculated based on these parameters. The amount of coarse saw residue (slabs, log end off-cuts, edgings, trimmings etc.) and sawdust were not measured and were not included in the research.

In a primary sawmill, lumber volume yield is defined as the ratio of the sawn board volume and log volume according to equation (2):

$$Y_{volume_{\log} \to board} = \frac{V_{board_{30}} + V_{board_{50}}}{V_{\log}} \bullet 100 \qquad (2)$$

where: $Y_{\text{Volume log}\rightarrow\text{board}}$ – lumber volume yield, %; $V_{\text{log}}$ – log volume, m$^3$; $V_{\text{board 30}}$ – sawn board volume of a nominal thickness of 30 mm, m$^3$; $V_{\text{board 50}}$ – sawn board volume of a nominal thickness of 50 mm, m$^3$.

***Figure 1.** Black walnut logs and sawn boards*

## 4. RESULTS AND DISCUSSION

The total of 5.794 m$^3$ of 1$^{st}$ class veneer logs was sawn into 3.888 m$^3$ sawn boards, 28.016 m$^3$ of 2$^{nd}$ class veneer logs was sawn into 18.821 m$^3$ sawn boards, 17.917 m$^3$ of 1$^{st}$ class saw logs was sawn into 11.570 m$^3$ sawn boards and 4.758 m$^3$ of 2$^{nd}$ class saw logs was sawn into 3.035 m$^3$ sawn boards. Descriptive statistical analysis of data on its dimensions is shown in Tables 1. and 2. Each log quality group is presented separately. Comparison of log mid-diameter and length are shown in Figures 2 and 3. Lumber volume yield of all logs is presented in Table 3 and in Figure 4.

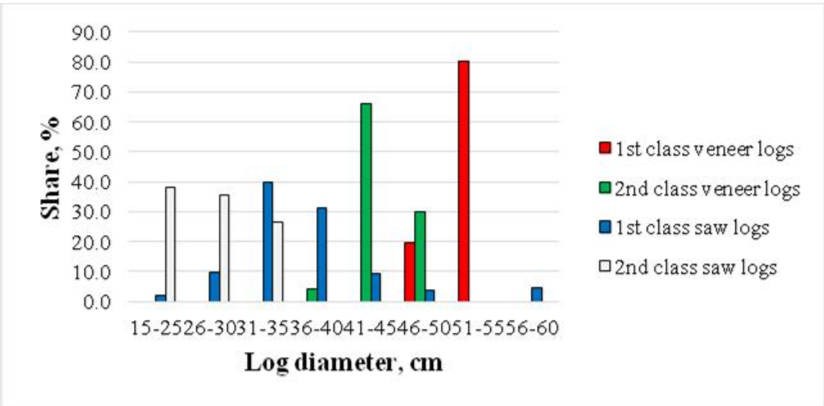


***Figure 2.** The share of diameters by class logs*

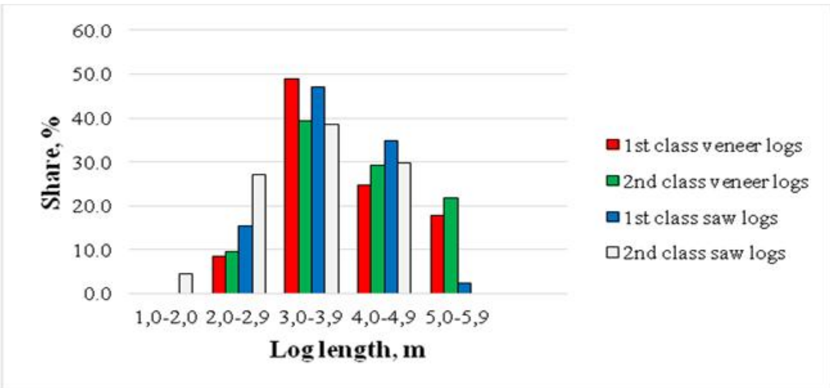


***Figure 3.** Proportion of the length of logs by class*

***Table 1***. *Descriptive statistics for the dimensions of Black walnut logs*

| Log size | 1st class veneer logs | | | | | |
|---|---|---|---|---|---|---|
| | N | Min. | Median | Max. | Average | Std. dev. |
| **Length, m** | 7 | 2.40 | 3.50 | 5.00 | 3.59 | 0.86 |
| **Mid diameter, cm** | 7 | 48.00 | 51.00 | 65.00 | 53.14 | 5.93 |
| **Volume, $m^3$** | 7 | 0.492 | 0.781 | 1.433 | 0.828 | 0.334 |
| **Log size** | **2nd class veneer logs** | | | | | |
| | N | Min. | Median | Max. | Average | Std. dev. |
| **Length, m** | 49 | 2.20 | 3.60 | 5.80 | 3.84 | 0.96 |
| **Mid diameter, cm** | 49 | 38.00 | 43.00 | 49.00 | 43.16 | 2.99 |
| **Volume, $m^3$** | 49 | 0.276 | 0.506 | 0.995 | 0.572 | 0.185 |
| **Log size** | **1st class saw logs** | | | | | |
| | N | Min. | Median | Max. | Average | Std. dev. |
| **Length, m** | 54 | 2.00 | 3.40 | 5.20 | 3.47 | 0.77 |
| **Mid diameter, cm** | 54 | 22.00 | 34.00 | 58.00 | 34.46 | 6.10 |
| **Volume, $m^3$** | 54 | 0.087 | 0.317 | 0.792 | 0.332 | 0.134 |
| **Log size** | **2nd class saw logs** | | | | | |
| | N | Min. | Median | Max. | Average | Std. dev. |
| **Length, m** | 27 | 1.60 | 3.20 | 4.40 | 3.18 | 0.78 |
| **Mid diameter, cm** | 27 | 19.00 | 25.00 | 33.00 | 26.07 | 3.81 |
| **Volume, $m^3$** | 27 | 0.060 | 0.166 | 0.338 | 0.176 | 0.071 |

***Table 2.*** *Descriptive statistics for the dimensions of Black walnut sawn boards*

| Sawn board size | 1st class veneer logs | | | | | |
|---|---|---|---|---|---|---|
| | N | Min. | Median | Max. | *Average* | Std. dev. |
| **Length, m** | 64 | 1.1 | 3.2 | 5 | 3.22 | 0.9135 |
| **Width, cm** | 64 | 13 | 40 | 51 | 36.8 | 9.87350 |
| **Volume, $m^3$** | 64 | 0.00693 | 0.06122 | 0.12810 | 0.06107 | 0.03358 |
| **Sawn board size** | **2nd class veneer logs** | | | | | |
| | N | Min. | Median | Max. | *Average* | Std. dev. |
| **Length, m** | 217 | 1 | 3.5 | 5.2 | 3.51 | 0.90504 |
| **Width, cm** | 217 | 11 | 26 | 38 | 25.17 | 7.09482 |
| **Volume, $m^3$** | 217 | 0.0042 | 0.03072 | 0.08325 | 0.03099 | 0.01556 |
| **Sawn board size** | **1st class saw logs** | | | | | |
| | N | Min. | Median | Max. | *Average* | Std. dev. |
| **Length, m** | 377 | 1 | 3.25 | 5.2 | 3.22 | 0.90 |
| **Width, cm** | 377 | 11 | 25 | 49 | 24.54 | 7.71 |
| **Volume, $m^3$** | 377 | 0.00290 | 0.03285 | 0.08325 | 0.03212 | 0.01783 |
| **Sawn board size** | **2nd class saw logs** | | | | | |
| | N | Min. | Median | Max. | *Average* | Std. dev. |
| **Length, m** | 116 | 0.7 | 2.95 | 4.4 | 2.90 | 0.94187 |
| **Width, cm** | 116 | 11 | 20 | 31 | 19.51 | 5.19949 |
| **Volume, $m^3$** | 116 | 0.00281 | 0.02605 | 0.05400 | 0.02616 | 0,01473 |

***Table 3.*** *Lumber volume yield of all logs*

| **Class of logs** | $Y_{\text{Volume log ì board}}$ | | | | | |
|---|---|---|---|---|---|---|
| | **N** | **Min.** | **Median** | **Max.** | ***Average*** | **Std. dev.** |
| **1st class veneer logs** | 7 | 62.9 | 65.8 | 72.1 | 67.3 | 3.7 |
| **2nd class veneer logs** | 49 | 54.6 | 66.6 | 78.1 | 66.6 | 5.0 |
| **1st class saw logs** | 54 | 52.3 | 65.1 | 81.6 | 65.1 | 6.1 |
| **2nd class saw logs** | 27 | 48.0 | 63.7 | 82.5 | 63.8 | 9.4 |

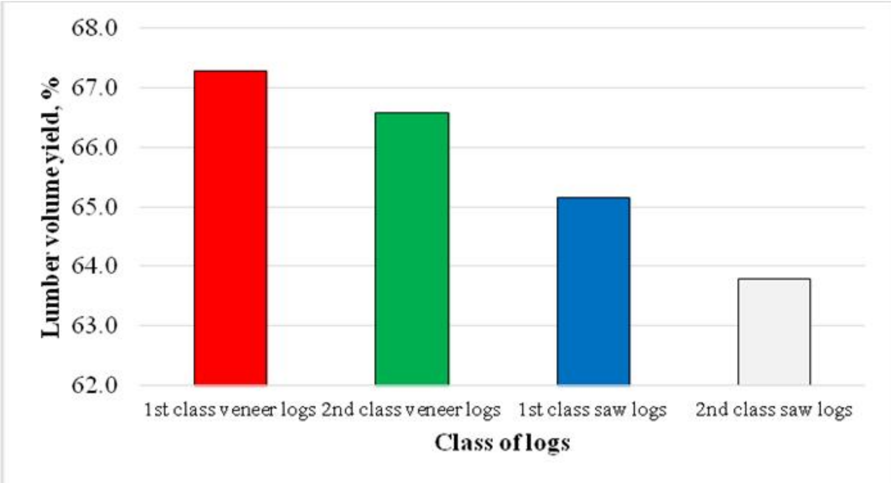


***Figure 4.*** *Comparison of average lumber volume yields*

In analyzing the results of lumber volume yield, results indicated that the best yield came from 1st class veneer logs, followed by 2nd class veneer logs, and then equally by 1st and 2nd class saw logs. These results appear to be correlated to the quality and dimensional structure of the log being sawn. Statistical analysis indicates that, in both quality grades veneer logs have somewhat greater dimensions in terms of diameter and length (Tables 1 and Figures 2 and 3.). In producing unedged sawn boards, these factors can have a significant effect on the volume yield. This was reflected in the results of the veneer logs.

The results obtained compared to Dunmire et al. (1972) showed more values. Compared with the previous researches on the performance of sawmill processing of common walnut Rabadjiski et al. (2015) obtained the same results or somewhat worse Prka et al. (2001) and Ištvanić et al. (2016). The circumstances and the conditions of these researches should be taken into account when making comparisons.

## 5. CONCLUSION

- Black walnut is a poorly represented in wood species in Croatia and grows only in the area of Eastern Slavonia,
- Research on the success of sawmill processing of black walnuts in these areas is very rare,
- Lumber Volume yield of the 1st class veneer logs was 67.3%, the 2nd class veneer logs were 66.6%, the 1st class saw logs were 65.1%, and the 2nd class saw logs were 63.8%,
- The 1st class veneer logs proved to produce the best lumber volume yield results. The 2nd class sawmilling logs proved to produce the worst volume yield results,
- Overall, the research results confirm increased volume yield with better logs quality and diameter. The results indicate a possibility of rational processing of the researched black walnut logs in sawmills,
- It would be interesting to conduct further researches of sawn boards, first in elements, then in glued massive wood panels.

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**The Authors´ Addresses:**

**Assistant professor Josip Ištvanić, Ph.D.;**
**Assistant professor Krešimir Greger, Ph.D.;**
**Ivana Perić, Ph.D.; *Associate professor**
**Alan Antonović, Ph.D.**

Wood Technology Department, Faculty of Forestry, University of Zagreb, Svetošimunska 25, 10000 Zagreb, Republic of Croatia
e-mail: jistvanic@sumfak.hr; kgreger@sumfak.hr; iperic@sumfak.h; aantonovic@sumfak.hr

**Marko Pečenec, mag. ing. techn. lign.**
Joinery and sawmill Antun Pečenec Ltd., Kapela Podravska 141, 42231 Mali Bukovec, Republic of Croatia; e-mail: pecenec@pecenec.hr
*Corresponding author