Inferential Statistics of *Quercus* Species in Veneer Cutting

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*Quercus* species represent 18% of the total forest area in Romania, of which 2% refers to common oak and 10.5% refers to sessile oak. These species are of special importance for Romanian silviculture due to their value in multiple industrial uses. The finest and most efficient use of valuable timber is wood veneer. This paper presents a comparative analysis of the efficiency in veneer cutting for two *Quercus* species, common oak and sessile oak, originating from the Snagov area in Romania. The statistical parameters of veneer efficiency were estimated with high accuracy by using the least squares method with a 95% normal confidence interval based on the Anderson-Darling test and the correlation coefficient. The analysis of inferential statistics used the estimation of the 87th percentile, determining the cumulative density functions for the species under study. More defects were found in common oak logs than in sessile oak logs, which produced more veneer sheets. The veneer efficiency for sessile oak logs was superior to that of common oak logs. These findings might have practical applications in industrial conditions when screening for the best log species with high efficiency in veneer cutting.

Keywords: Common oak; Log defects; Sessile oak; Veneer efficiency

INTRODUCTION

The *Quercus* genus belongs to the Fagaceae family, and it comprises of about 350 to 500 species with great technical, economical, and ecologic potential (Kubitzki 1993; Viscosi et al. 2009). *Quercus* species are spread throughout the northern hemisphere down to the equator (Axelrod 1983). They are found in Asia, North America, Europe, and Africa. Approximately 20 oak species grow in the Mediterranean area. In Europe 27 native species of *Quercus* genus are found, of which the common oak (*Quercus robur* L.) and sessile oak (*Quercus petraea* (Mattuschka) Liebl.) are the two most common and valuable species (Mabberley 1990; Petritan et al. 2012).

These species adapt to extremely variable habitats, from sea level to 4000 m in the Himalayas, and from swamps to deserts. Oaks are considered post-pioneer and light demanding species (Timbal and Aussenac 1996). In terms of site requirements, common oak and sessile oak may grow together on a wide range of soils. The former grows in wet areas, while the latter is quite tolerant to drought and poor soil (Popa et al. 2013).

Thomas et al. (2002) reported that various abiotic and biotic factors have been
related to oak decline in Europe, and several studies in last decade show the role of oaks in their natural range (Friedrichs et al. 2009; Mérian et al. 2011). Sessile oak copes better with expected climate change in pure and mixed stands (Bergès et al. 2005).

Romania is located in the continental temperate region and therefore presents optimal conditions to grow *Quercus* species (FAO 1995). Romanian forests consist of 69.3% hardwood species and 30.7% softwoods. The main species are 32% beech, 19% spruce, 18% oak, 17% diverse hard hardwoods, 7% diverse soft hardwoods, 5% fir, and 2% other softwoods. *Quercus* species comprise 2% common oak and 10.5% sessile oak (Ministry of Water and Forests 2016). Sessile oak covers 500,000 ha in Romania, and it is the most widespread indigenous *Quercus* species (Nicolescu 2010). Pure common oak and mixed *Quercus* stands are located in Romania in low hilly and subcolinary meadows under a fragmented repartition, but they are well-represented at altitudes from 140 m to 350 m. The species grow on luvo-soils under a relatively wet and cold climate with annual average temperatures of about 6 °C to 9 °C and precipitations of about 600 mm to 900 mm. These valuable species present special importance for the Romanian economy (Şofletea and Curtu 2007; Budeanu et al. 2016).

Various publications have approached the two species under scientific screening related to wood quality (Zhang et al. 1994; Feuillat and Keller 1997; Doussot et al. 2002; Attocchi 2015), defects (Kruch and Nicolescu 2010; Kruch 2011; Dumitrascu et al. 2013), genetic variations and control of specific features (Savill et al. 1993; Mosedale et al. 1996; Kremer and Zanetto 1997), and regeneration patterns in relation with the environment (Indreica and Kelemen 2011; Annighofer et al. 2015).

*Quercus* species timber has been the most demanded and highly valued timber in the European market (Bary-Lenger and Nebout 1993). Its position dominates the flooring and joinery industry (UNECE/FAO 2012). Common oak and sessile oak present a considerable economic value in the wood processing industry especially; they are used in construction, furniture manufacturing and veneer production, barrels, and fencing (Kruch and Nicolescu 2010; Nicolescu 2010; Todaro et al. 2012; Annighofer et al. 2015).

In Romania several home-grown wood species are used for decorative veneer production, such as larch, oak, maple, walnut, cherry, ash. Two of the *Quercus* species, namely the common oak and sessile oak are granted with a special attention in the art furniture industry. There is no mass veneer production for these species.

The most efficient use of any valuable species is through its veneer by using modern veneer production technology (Ozasrka 2013). The value of a veneer tree is determined by the interaction of several factors, such as the timber stand, site, and soil type (Feuillat and Keller 1997). Only high-quality, defect-free logs are used to produce veneers, and each wood species is individually processed based on the cutting scheme set by the company (Musat et al. 2016, 2017). The quality of logs in the production line gives the yield in veneer cutting at the end (Lutz 1977; Wiedenbeck et al. 2003; Dobner et al. 2013; McGavin et al. 2014).

The classification of quality defects of wood species is specified in the European standard SR EN 1316-1 (2013) with respect to common oak and sessile oak, which also includes the quantified sapwood width for logs quality classification. Also, the standard classifies the *Quercus* logs for veneer into three grades according to their diameter, length, and non-acceptable defects.

The major difficulty hindering the high-efficiency marketing of such wood species is the fact that most of the features and defects newly introduced into SR EN 1316-1 are not reflected in the Romanian standards, such as the frequency of spreading, size, and log
distribution (Dumitrascu et al. 2013).

This paper presents a comparative analysis of the efficiency in veneer cutting for two Quercus species, common oak and sessile oak, originating from the Snagov area in Romania by using inferential statistics. The statistical parameters of veneer efficiency were estimated with high accuracy by using the least squares method with a 95% normal confidence interval based on the Anderson-Darling test and the correlation coefficient. The analysis of inferential statistics used the estimation of the 87th percentile, determining the cumulative density functions for the species under study. The study aims to identify and evaluate the possible differences that may appear in regard to the efficiency in veneer cutting when considering the quality defects and number of veneer sheets. Findings of this study might have brief practical applications under industrial conditions when screening for the best species with high efficiency in veneer cutting.

**EXPERIMENTAL**

**Materials**

Logs of two species, common oak (Quercus robur L.) and sessile oak (Quercus petraea (Mattuschka), were purchased from Snagov Forest Direction in Romania. The Snagov Direction, subordinated to the National Forest Direction, administers the state public forests from the northern part of Ilfov County and provides silvicultural services to the private forests in the area. The forests of Snagov Direction are distributed in the flat plains area surrounding Bucharest and are part of the famous Vlasia Forests. The Snagov Direction has a total surface of 9495 ha with the following composition: 53% Quercus species, of which 35% is pedunculated oak; 23% hard hardwoods, 20% soft hardwoods, and 4% other species.

**Method**

A total of 215 logs were selected according to the SR EN 1316-1 (2013) standard from the same location of Snagov region; 165 common oak logs and 50 sessile oak logs have been analyzed with the consideration that the samples size was representative. In accordance with the specified standard the selection criteria are both quantitative and qualitative. The main statistical parameters of common oak and sessile oak raw material are detailed in Table 1.

**Table 1. Descriptive Statistic of Raw Material for the Analyzed Species**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Common oak</th>
<th>Sessile oak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (cm)</td>
<td>Min: 44</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Median: 64</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Max: 94</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Mean: 64.638</td>
<td>76.72</td>
</tr>
<tr>
<td></td>
<td>SD: 11.196</td>
<td>10.45</td>
</tr>
<tr>
<td>Length (m)</td>
<td>Min: 2.2</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Median: 2.9</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>Max: 3.9</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Mean: 3.0281</td>
<td>2.9759</td>
</tr>
<tr>
<td></td>
<td>SD: 0.3949</td>
<td>0.3008</td>
</tr>
<tr>
<td>Volume (m³)</td>
<td>Min: 0.3950</td>
<td>0.8690</td>
</tr>
<tr>
<td></td>
<td>Median: 0.9620</td>
<td>1.4790</td>
</tr>
<tr>
<td></td>
<td>Max: 2.4980</td>
<td>2.4980</td>
</tr>
<tr>
<td></td>
<td>Mean: 1.0334</td>
<td>1.4154</td>
</tr>
<tr>
<td></td>
<td>SD: 0.4047</td>
<td>0.4657</td>
</tr>
</tbody>
</table>

The efficiency in veneer cutting was determined based on total losses in veneer production (Musat et al. 2016), while the efficiency in special veneer cutting was expressed...
as the number of finished products resulting from 1 m³ wood and ranked in the first quality class (Dumitrascu et al. 2013). The same veneer cutting technology was applied for common oak and sessile oak logs (Musat et al. 2017). The logs were cut into splitwoods and heat-treated, and sliced veneer sheets of 0.55 mm thickness were obtained from each log. The veneer sheets were subjected to drying, conditioning, and sizing at the end of the processing line.

To compare the two wood species, a statistical analysis was gradually applied to the efficiency in veneer and special veneer cutting, the number of veneer sheets, and the distribution of log defects.

No more than two acceptable defects were allowed to occur on the same log, such as the following: curvature and buds, wood studs and buds, insect holes and buds, conicity and buds, curvature and wood studs, and buttress roots and buds. The results indicated an acceptable level of defects for the logs under study.

The experimental data analysis was performed by using Minitab. In order to estimate the statistical parameters of efficiency in veneers and special veneers cutting, the statistical analysis consists of identifying the statistical distribution using the Anderson-Darling goodness-of-fit test (NIST 2013). The statistical model was validated considering 95% confidence interval and the estimated correlation coefficient. When using the Minitab program, the parameters can be estimated by two estimation methods: maximum likelihood and least squares. In this regard, the statistical parameters of veneer efficiency and special veneer efficiency were estimated with high accuracy by using the least squares method with a 95% normal confidence interval.

To make a comparative analysis between the veneer and special veneer efficiency for the two species, the cumulative density functions were used. The method allowed the estimation of 87th percentile specific to each species.

RESULTS AND DISCUSSION

The parameters estimation of veneer efficiency for common oak and sessile oak is presented in Tables 2 and 3, and the distribution analysis of veneer efficiency for the two species is shown in Figs. 1 and 2.

The probability plot was used to evaluate whether or not a data set followed a given distribution and to compare different sample distributions. The visual inspection on the probability plots revealed that the analyzed samples were homogeneous. The estimated values of the Anderson-Darling test and the correlation coefficient indicated that the analyzed data followed the normal distribution with a confidence interval of 95% and a value of parameter \( p \geq 5\% \), as displayed in Figs. 1 and 2.

The comparative analysis of the efficiency in veneers and special veneers cutting used the estimation of the 87th percentile by determining the cumulative density functions for the species under study (Figs. 3 and 4).

The statistical significance of the differences between species regarding the veneer and special veneer efficiency showed that the sessile oak logs presented a better cutting efficiency than the common oak logs. This conclusion was also supported by the number of veneer sheets obtained from the sessile oak logs (Fig. 5).
Table 2. Parameters Estimation of Veneer Efficiency for Common Oak

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard Error</th>
<th>95% Normal CI</th>
<th>Goodness of Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Mean</td>
<td>20.2267</td>
<td>743.554</td>
<td>822.841</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>14.4502</td>
<td>248.200</td>
<td>304.944</td>
</tr>
</tbody>
</table>

Table 3. Parameters Estimation of Veneer Efficiency for Sessile Oak

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard Error</th>
<th>95% Normal CI</th>
<th>Goodness of Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Mean</td>
<td>36.4260</td>
<td>927.868</td>
<td>1070.66</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>27.5179</td>
<td>149.005</td>
<td>258.238</td>
</tr>
</tbody>
</table>

Fig. 1. Distribution analysis of veneer efficiency for common oak and sessile oak logs
Fig. 2. Distribution analysis of special veneer efficiency for common oak and sessile oak logs

Fig. 3. Cumulative density function of veneer efficiency for common oak and sessile oak logs
Fig. 4. Cumulative density function of special veneer efficiency for common oak and sessile oak logs.

Fig. 5. Comparative analysis of number of veneer sheets from common oak and sessile oak logs.
The boxplot diagram indicated that the sessile oak presented a higher median value when compared to common oak, even when three values of the common oak exceeded the maximum estimated limit. It was also observed that the data dispersions were comparable.

Table 4. Comparative Analysis of the Veneer Efficiency

<table>
<thead>
<tr>
<th>Species</th>
<th>87th Percentile</th>
<th>No. of sheets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Veneer efficiency</td>
<td>Special veneer efficiency</td>
</tr>
<tr>
<td>Common Oak</td>
<td>1092</td>
<td>957</td>
</tr>
<tr>
<td>Sessile Oak</td>
<td>1215</td>
<td>1106</td>
</tr>
</tbody>
</table>

The differences displayed in Table 4 were also influenced by the quality acceptable defects of the raw material in accordance with SR EN 1316-1 (2013). The veneer efficiency in the case of sessile oak logs was superior to common oak logs, and it was confirmed by the low rate of defects within the log samples under study growing under the same location conditions.

![Fig. 6. Interval plot of defects for common oak and sessile oak logs](image)

The statistical significance of the differences between the two species in regard to their defects approached the comparison of mean values with the 95% confidence interval (Fig. 6). The conicity, curvature, insect holes, buds, wood studs, and buttress roots were the defects identified and accepted on sessile oak and common oak logs.
CONCLUSIONS

1. The cumulative density functions specific to each of the two species allowed for inter-
   comparison of the veneer and special veneer efficiency when considering the 87th
   percentile estimation with a confidence interval of 95%.

2. The log quality defects were found for both species in accordance with the specific
   standard, and they influenced the veneer efficiency in both cases.

3. The log quality influenced the veneer efficiency. It was found that common oak logs
   presented more defects than sessile oak logs, which produced more veneer sheets.
   Moreover the veneer efficiency for sessile oak logs was found to be superior to that of
   common oak logs.

4. The findings of this study might have brief practical applications under industrial
   conditions when screening for the best species with high efficiency in veneer cutting.

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