Quality of pedunculate oak Provenances in Bosnian–Herzegovinian provenance test based on branching angle and stem form

Dallanma açısı ve gövde formuna dayalı köken belirleme testine göre Bosna-Hersek’teki saplı meşelerin kalitesi

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ABSTRACT

Pedunculate oak (Quercus robur L.) populations in Bosnia and Herzegovina are significant for species preservation in Europe because of their specific genetic structure. For conservation purposes, we established a provenance test in 2009 in Žepče, with 28 provenances. In 2019, we evaluated branching angles and stem form of plants through a provenance test to assess their quality. Plants with branching angle <22.5° was found with 2% of the total number of plants, branching angle 22.5°–45° in 19% of plants, branching angle 45°–67.5° in 32% of plants, and branching angle 67.5°–90° in 47% of plants. The highest percentage of the most favorable branching angle had a provenance from Ključ, Miljevina Foča, and Bugojno. Category 10 of stem form (ideal tree, without defect) was found in 14% of the plants, category 9 (a small defect) in 16%, category 8 (two slight defects) in 3%, category 7 (two medium defects or many small defects) in 4%, category 6 (big defects that can be recovered or more medium defects) in 16%, and category 5 (many defects) in 7% of the total number of plants. In category 4, the researchers recorded all the plants without silvicultural value, and it included 40% of the plants. The highest percentage of category 10 plants had a Drvar provenance (42%), whereas the lowest had a Bugojno provenance (2%). These results are important in assessing the quality of provenances and need to be followed by research of other morphological traits and genetic variability.

Keywords: Quercus robur, branching angle, stem form, provenance test, quality of provenances

ÖZ

Bosna-Hersek’teki saplı meşe (Quercus robur L.) populasyonları, spesifik genetik yapıları nedeniyle Avrupa’daki türlü korunması için önem arz etmektedir. Bu ağaçların korunması amacıyla, 2009 yılında Žepče de 28 adet köken ile birlikte köken belirleme testi oluşturulmuştur. 2019 yılında, köken belirleme testi ile dallanma açıları ve kök formları da değerlendirilerek bir kalite belirlemesi yapılmıştır. Dallanma açısı 22.5° altında olan ağacların toplam açığın %2’sini, dallanma açısı 22.5°–45° arasında olan ağacların toplam açığın %19’unu, dallanma açısı 45°–67.5° arasında olan ağacların toplam açığın %32’sini ve dallanma açısı 67.5°–90° arasında olan ağacların toplam açığın %47’sini oluşturduğu tespit edilmiştir. En uygun dallanma açısı en yüksek yüzden Kaynağı Ključ, Miljevina Foča ve Bugojno bölgelerindeki kökenlike sahip olduğu görülmüştür. Kök formunun 10. kategorisi (ideal ağaç, hatasız ağaçların %14’ünde, kategori 9 (küçük bir kusur) ağaçların %16’sında, kategori 8 (iki hafif kusur) ağaçların %3’ünde, kategori 7 (iki orta kusur veya birçok küçük kusur) ağaçların %4’ünde, kategori 6 (iki orta kusur veya birçok küçük kusur) ağaçların %7’sinde ve kategori 5 (içinleri ve kategori 8’sinde tespit edilmiştir. 4. kategoride silvikültürel değer無い olan tüm ağaclar kaydedilmiş ve bu kategoride %40 oranında ağaç bulunduğunu görmüştür. Kategori 10 da bulunan ağacların en yüksek yüzde Dvrar bölgesinde kökenlike (%42) sahipken, en düşük 4. kategoride bulunan ağacların Bugojno bölgesi kökenlike (%2) sahip olduğu tespit edilmiştir. Bu sonuçlar, kökenlerin belirlenmesinin kalite değerlendirmelerinde önemli olduğunu ve diğer morfolojik özelliklerin ve genetik değişkenliğin takip edilerek araştırma yapılmasını gerektirdiği ortaya koymaktadır.

Anahtar Kelimeler: Quercus robur, dallanma açı, gövde formu, köken belirleme testi, köken kalitesi

INTRODUCTION

The populations of pedunculate oak (Quercus robur L.) represent the remains of formerly large populations of this species in Bosnia and Herzegovina. They are located on the southern edge of the
range of the species. These populations are significant for the conservation of pedunculate oak in Bosnia and Herzegovina and Europe because of their specific genetic structure.

To conserve the species, the researchers established a Bosnian-Herzegovinian provenance experiment of pedunculate oak in Žepče in 2009.

This study aims to discover the morphological variability of the branching angle properties and the shape of the stem to determine the quality of provenances and to select those provenances whose characteristics correspond to the desired ones in terms of producing the highest wood pulp quality.

Previous researches of branching angle and stem shape are generally rare. Pintarić (1974) investigated the branching angle in larch provenances. Kint et al. (2010) investigated the modeling of branch clearing and branch characteristics on young trees of pedunculate oak and common beech. They defined the variables and assumed the values for the models. The assumed parameters for branch insertion angle according to their model for pedunculate oak were: minimum insertion 5°, maximum 103°, mean 49.2°, and a standard deviation of 16.9°. Kuehne et al. (2013) investigated the growth and shape of pedunculate oak and common ash stem depending on the initially available space in a 24-year experiment. The results showed that the initially available space considerably affects the shape of the stem of both species. They evaluated the shape of the stem in four categories (1: straight, 2: bent, 3: crooked, and 4: deformed) and obtained the best stem shape ratio at the initially available space of 0.33 m² (only straight and bent trees).

The morphological variability of leaves of pedunculate oak populations in the Western Balkans, including Bosnia and Herzegovina and populations included in the provenance experiment, was investigated by Memišević (2010) and Ballian et al. (2010). The results showed the existence of intra-provenance and inter-provenance variability.

Provenance experiments that included the height increment and root neck growth of pedunculate oak in Žepče were done by Ballian et al. (2011), Ballian and Memišević Hodžić (2016), Memišević Hodžić (2015), Memišević Hodžić and Ballian (2016a), and Memišević Hodžić et al. (2016b, 2019). Their results showed statistically significant inter-provenance variability.

The genetic variability of pedunculate oak in Bosnia and Herzegovina was investigated by Ballian and Memišević Hodžić (2016), Memišević Hodžić (2015), and Memišević Hodžić and Ballian (2016, 2018, 2019). They found inter-provenance variability of genetic variability traits (heterozygosity, fixation index, and gene pool diversity).

Branching angle and stem form are very important traits to determine the provenances that will produce high-quality wood mass. The study aims to determine the quality of pedunculate oak in Bosnia and Herzegovina through a provenance test based on branching angle and stem form.

MATERIALS AND METHODS

The researchers assessed the branching angle and stem shape of pedunculate oak plants in the Bosnian-Herzegovinian provenance test in Žepče. The provenance test contains 28 provenances from Bosnia and Herzegovina (Table 1, Figure 1).

The experiment was established by planting one-year-old seedlings in 2009. The seedlings were planted in 30 cm × 30 cm × 30 cm holes, with a planting distance of 2 m × 2 m. The seedlings were planted in three blocks, with 36 plants per provenance in one block. Two rows of seedlings were planted around each block to reduce the edge effects on the experimental plot. Ame liorative measures or cleaning was not carried out from planting to conducting the research. The spatial arrangement of planting of the provenances is shown in Figure 2.

In autumn of 2019, the researchers evaluated branching angle and stem form. At the time of evaluation, the plants were already 11-years-old.

According to Ducci et al. (2012), branch angle is defined as the angle between a given branch or the mean angle of branches and the main stem axis. In case of branch curvature, the angle is measured at the insertion point (line y in Figure 3).

The researchers distinguished six categories (1-5), as defined by Ducci et al. (2012) and shown in Figures 3 and 4. For measuring, the researchers used a simple protractor. The researchers estimated branch angle classes for two whorls that is located just under and above half of the total tree height, and it is calculated as the average of both estimates.

For stem form evaluation, the researchers used the scoring system for beech and oak defined by Ducci et al. (2012) as shown in Figure 5. According to their study of beech and oak spp., the dichotomous scoring system may include a continuous range of stem form situations from no silvicultural value (e.g., shrubby trees) up to top-quality straight trees.

The scoring system is as follows:

No silviculture value (even with human intervention, such as pruning)
- No main axis: 1-2
- One main axis: 3-4

Silviculture value
- Severe defects on main axis: 5-6
- Slight defects on main axis: 7-8
- One defect: 9
- Straight main axis: 10

While the researchers were not interested in plants with no silviculture value (1-4), the researchers did not distinguish them but recorded them all as category (4).
Statistical Analyses
The researchers performed statistical analysis using IBM Statistical Package for the Social Sciences (IBM SPSS Corp.; Armonk, NY, USA) version 20.0. The researchers looked at histograms of the data to check normality of distribution instead of normality tests, because the samples was of a large size. The researchers calculated the frequencies of different categories of branching angle and stem form per provenances using SPSS Crosstabs command, and performed variance analysis for both traits using ANOVA command.

Ethics Committee Approval: There is no need for ethics committee approval for this subject.

RESULTS AND DISCUSSION

Branching Angle
The results for branching angle (Table 2; Figure 6) showed that 2% of the total number of plants in the provenance experiment had branching angles marked with 1 (<22.5°), 19% had branching angles marked with 2 (22.5-45°), 32% had branching angles marked with 3 (45-67.5°), and 47% had branching angles marked with 4 (67.5-90°). There were no plants with branching angles marked with 5 (90-112.5°).

The highest percentage of the most favorable presented branching angles (category 4) had provenance Kjuc (68%), fol-
Figure 1. The investigated provenances

| Railway  | Block III | Block II | Block I |
|----------|-----------|----------|---------|
| Zavidović | Mrkonjić | Olovo | Kiseljak |
| Sokolac | Bosanski | Kačuni | Bosanska |
| Vinar | Popuna | Reda |
| Vinac | Popuna | Reda |
| Jelah | Kotor | Vario |
| Popuna | Pražne | Plovice |
| Path in the nursery | Path in the nursery |

Figure 2. The spatial arrangement of planting of provenances in the Quercus robur provenance test
Followed by Miljevina Foča (67%), and Bugojno (64%). The lowest percentages of branching angles (category 4) had provenances Mutnica Cazin (11%) and Bosanska Dubica (25%).

The results of the variance analysis are shown in Table 3. F calculated (5,24) was higher than F from the F-distribution table (for 27 and 2375 (∞)=1,48), which means that there is a statistically significant difference between the investigated provenances for the branching angle property (with p=0.05).

| Provenance         | 1  | 2  | 3  | 4  |
|--------------------|----|----|----|----|
| Bijeljina          | 2  | 25 | 32 | 42 |
| Bosanska Dubica    | 5  | 33 | 37 | 25 |
| Bosanska Gradiška  | 4  | 30 | 31 | 34 |
| Bosanski Brod      | 6  | 16 | 31 | 46 |
| Bosansko Grahovo   | 2  | 11 | 28 | 58 |
| Bugojno            | 0  | 9  | 27 | 64 |
| Drvar              | 8  | 27 | 33 | 33 |
| Hrgovi Srebrenik   | 1  | 22 | 26 | 52 |
| Jelah              | 7  | 21 | 31 | 41 |
| Kačuni             | 1  | 22 | 36 | 42 |
| Kiseljak           | 2  | 29 | 37 | 32 |
| Ključ              | 1  | 4  | 27 | 68 |
| Knežina            | 1  | 15 | 35 | 49 |
| Kotor Varoš        | 3  | 14 | 41 | 42 |
| Lukavica           | 0  | 16 | 31 | 54 |
| Miljevina Foča     | 0  | 12 | 21 | 67 |
| Mrk. Grad           | 1  | 13 | 32 | 54 |
| Mutnica Cazin      | 2  | 32 | 55 | 11 |
| Nević Polje        | 3  | 16 | 27 | 54 |
| Novi Seher         | 1  | 28 | 21 | 49 |
| Olovo              | 2  | 22 | 32 | 44 |
| Sokolac            | 2  | 18 | 29 | 51 |
| Stojčevac          | 4  | 21 | 21 | 54 |
| Vinac              | 1  | 21 | 21 | 56 |
| Visoko Muhašinovići| 1  | 15 | 34 | 51 |
| Zavidovići         | 4  | 16 | 28 | 53 |
| Žepče              | 3  | 16 | 40 | 41 |
| Živinice            | 0  | 11 | 47 | 42 |

Total 2 19 32 47

Table 2. Branching angle categories (in % of the total number of plants) per provenances

F calculated (5,24) was higher than F from the F-distribution table (for 27 and 2375 (∞)=1,48), which means that there is a statistically significant difference between the investigated provenances for the branching angle property (with p=0.05).

Stem Form
The results for stem form (Table 4; Figure 7) showed that the ideal stem form category had 14% of the total number of plants in the provenance test. The highest percentage of such plants had Drvar provenance (42%) and the lowest had Bugojno provenance (2%). Moreover, 16% of the plants had small defects. The highest percentage of such plants had Žepče and Zavidovići provenances (25%), and the lowest had Lukavica and Stojčevac provenances (6%). Furthermore, 3% of plants had two slight defects, 4% of plants had two medium defects.
or many small defects, and 16% of plants had big defects that can be recovered or more medium defects, whereas 7% of plants had many defects. The highest percentage of plants in this category had a Lukavica provenance (24%), and the lowest had Drvar provenance (0%). Also, 40% of the plants was without silvicultural value. The highest percentage of such plants (63%) had a Bosansko Grahovo provenance, and the lowest (20%) had a Drvar provenance.

The results of variance analysis are shown in Table 5.

Figure 5. The scoring system used for beech and oak

1) No main stem or on a low height ("apple" shape);
2) No apparent stem; very many major defects;
3) Presence of a visible stem, but several major defects;
4) Presence of a visible stem, but a major defects eliminates any forestry quality;
5) Trees having many defects (branching angle, branches diameter, branches density, flexuosity), but could be recovered with pruning;
6) Big defects that could be recovered, or more medium defects;
7) Two medium defects or many small defects; maximum score for a tree with multiple stem;
8) Two slight defects, or medium defect;
9) A small defect (fork at the top of the crown, slight flexuosity, branches with greater average diameters,...);
10) Ideal tree: no defect.
F calculated was (6.76) > F from the F-distribution table (for 27 and 2375 (∞)=1.48), which means that there is a statistically significant difference between the investigated provenances for the stem form property (with p=0.05).

Table 3. Variance analysis for branching angle

| Source of variability | Sum of squares | Df | Mean square | F    | Sig. |
|-----------------------|----------------|----|-------------|------|------|
| Between groups        | 94.598         | 27 | 3.504       | 5.238| 0.000|
| Within groups         | 1588.600       | 2375 | 0.669      |      |      |
| Total                 | 1683.199       | 2402 |             |      |      |

Table 4. Stem form categories per provenances

| Provenance  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|-------------|----|----|----|----|----|----|----|
| Bjeljina    | 33 | 14 | 15 | 5  | 2  | 14 | 17 |
| Bosanska Dubica | 21 | 5  | 20 | 4  | 2  | 15 | 33 |
| Bosanska Gradiška | 44 | 2  | 16 | 3  | 1  | 18 | 17 |
| Bosanski Brod  | 37 | 4  | 16 | 4  | 4  | 22 | 10 |
| Bosansko Grahovo | 63 | 2  | 19 | 1  | 2  | 7  | 6  |
| Bugojno     | 47 | 15 | 17 | 6  | 6  | 8  | 2  |
| Drvar       | 20 | 0  | 11 | 3  | 2  | 22 | 42 |
| Hrgovi Srebrenik | 31 | 3  | 22 | 2  | 2  | 15 | 25 |
| Jelah       | 36 | 5  | 11 | 3  | 4  | 16 | 25 |
| Kačuni      | 34 | 5  | 20 | 5  | 3  | 23 | 9  |
| Kiseljak    | 34 | 6  | 31 | 6  | 3  | 15 | 5  |
| Ključ       | 40 | 2  | 11 | 7  | 4  | 23 | 12 |
| Knežina     | 32 | 6  | 18 | 4  | 3  | 23 | 13 |
| Kotor Varoš | 39 | 7  | 14 | 4  | 2  | 23 | 10 |
| Lukavica    | 48 | 24 | 13 | 3  | 3  | 6  | 4  |
| Miljevina Foča | 47 | 7  | 17 | 6  | 2  | 15 | 5  |
| Mrkonjić Grad | 57 | 12 | 11 | 1  | 1  | 10 | 8  |
| Mutnica Cazin | 29 | 3  | 37 | 2  | 2  | 9  | 18 |
| Nević Polje | 37 | 12 | 10 | 4  | 3  | 12 | 21 |
| Novi Šeher  | 39 | 7  | 8  | 4  | 4  | 17 | 21 |
| Olovo       | 57 | 4  | 8  | 5  | 3  | 18 | 4  |
| Sokolac     | 43 | 3  | 14 | 6  | 3  | 13 | 18 |
| Stojčevac   | 59 | 6  | 15 | 4  | 4  | 6  | 6  |
| Vinac       | 34 | 11 | 13 | 5  | 5  | 18 | 15 |
| Visoko Muhašinovići | 49 | 13 | 13 | 6  | 4  | 7  | 7  |
| Zavidovići  | 40 | 5  | 9  | 9  | 6  | 25 | 5  |
| Žepče       | 37 | 4  | 18 | 2  | 2  | 25 | 12 |
| Živinice     | 37 | 6  | 24 | 3  | 2  | 17 | 11 |
| Total       | 40 | 7  | 16 | 4  | 3  | 16 | 14 |

There were no many studies of branching angle in the past. In Bosnia and Herzegovina, Pintarić (1974) investigated and scored the branching angle of 7-year-old larch provenances into
four categories (1: 90° angle or higher; 2: 70–90° angle; 3: 40–69° angle; and 4: 40° angle or lower). The results showed different branching angle category participation. In some provenances, he found only two; in others, he found all four categories of branch insertion. It indicated that if the forestry experts researchers want to obtain better quality individuals, they must intervene as early as possible in the early stages of development, preferably by removing trees with densely developed canopy and steep branches. In this research the authors obtained different branching angles as well. To choose provenances with the best wood mass quality, the researchers should choose the best individuals from the provenances.

Pintarić (1969, 1974) stated that in the selection of plus-trees and stand-care, the researchers should choose and assist the individuals or populations whose trees have higher branching angles, among other desirable traits. Such individuals are more resilient to damage from snow, clean themselves from branches faster, have a better-shaped trunk, and produce better wood quality.

Previous studies showed a close correlation in the position of branches between young and old trees. Trees with a larger branching angle need to be assisted in younger developmental stages (Pintarić, 1974).

Table 5. Variance analysis for stem form

| Source of variability | Sum of squares | Df | Mean square | F      | Sig. |
|-----------------------|----------------|----|-------------|--------|------|
| Between groups        | 918.242        | 27 | 34.009      | 6.704  | 0.000|
| Within groups         | 12047.402      | 2375 | 5.073       |        |      |
| Total                 | 12965.644      | 2402 |             |        |      |

Figure 6. Categories of branching angles (in % of total number of plants) per provenances
In this study, the percentage of plants with a branching angle of 67.5–90° is relatively good. According to previous studies, this branching angle range is considered favorable. The provenances, such as Bosanska Dubica, Bosanska Gradiška, Drvar, Kiseljak, and Mutnica Cazin, showed unfavorable ratios of branching angle categories (less than 40% in category 4).

Some of these provenances, such as Drvar and Bosanska Dubica, have low fixation index values, and heterozygosity was lower than expected. On another note, they are not among the worst provenances in height and diameter growth (Ballian et al., 2011; Ballian and Memišević Hodžić, 2016; Memišević Hodžić, 2015; Memišević Hodžić et al., 2016; Memišević Hodžić et al., 2019).

Oosterbaan et al. (2008) stated that for the production of high-quality wood of valuable hardwood species, the tree needs to have certain genetic characteristics (i.e., to grow straight and to have a monopodial tree crown). Forks and branches with sharp insertion angles should be avoided.

There were few researches of *Quercus robur* L. stem form.

Višnjić (2010) investigated the stem forms of nine-year-old beech plants in a provenance experiment that included provenances from Germany, Central and Southern Italy, Bosnia and Herzegovina, Slovenia, and Romania. He assessed the stem shapes and classified them into five categories (from a score of 1, which had well-branched trees with a well-defined stem, to 5, which had stems with many peaks and a shrubby form growing 5 cm above the ground). The average stem shape was 2.5, and the lowest and highest values were 1.7 at one German provenance and 3.6 at one Slovenian provenance, respectively.

Kint et al. (2010) investigated the modeling of branch clearing and branch characteristics of young pedunculate oak and common beech trees. They defined the corresponding variables and predicted the values that go into the models. The predicted parameters for the property of branch insertion angle according to their model for pedunculate oak were: minimum insertion=5°, maximum=103°, and mean=49.2°, with a standard deviation of 16.9°.

Kuehne et al. (2013) investigated the growth and shape of pedunculate oak and common ash stem depending on the initially available space in a 24-year experiment. They evaluated the stem shape and classified it into four categories (1: straight, 2: bent, 3: crooked, and 4: deformed). The results showed the high impact of initially available space on the stem shape of both species. The best stem shape ratio for pedunculate oak was at an initial space of 0.33 m² (only straight and bent trees). The
percentage of shrubs increased as the distance between trees increased. Considering that the planting distance in the provenance test was 2 m x 2 m, the researchers can partially explain non-favorable ratio of stem forms of the plants.

CONCLUSIONS

The researchers studied branching angle and stem shape of the provenance of pedunculate oak trees in the Bosnian-Herzegovinian provenance test to determine the quality of provenances. Provenances Klujić, Miljevina Foća, and Bugojno had the highest percentage of plants with branching angles favorable for the quality of wood mass. Provenances Mutnica Cazin and Bosanska Dubica had the lowest percentages of plants with branching angles favorable for the quality of wood mass. Provenances Drvar, Bosanska Dubica, and Hrgovi Srebrenik showed better structure by stem; while Bosansko Grahovo, Mrkonjić Grad, Olovo, and Stojčevac had bad structure, with more than 50% of the plants with stem form was without silvicultural value. Besides the genetic structure of the plants, non-favorable planting distance was one of the reasons for the bad ratio of stem form. For future management, the researchers should choose provenances with more favorable branch insertion angles and good stem shapes. Selection of phenotypically good trees was not possible because the seed material used to raise the trees in the provenance test was collected from the remaining populations. In the renewal of these stands, it is necessary to help the phenotypically best trees. The results of this study should be confirmed at the molecular and genetic level in the future.

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REFERENCES

- Ballian, D., Mekić, F., Murlin, I., Memišević, M., Bogunić, F., 2011. Preliminary results on the morphological features of up to 10-year-old pedunculate oak (Quercus robur L.) in Bosnian and Herzegovinian provenance tests. Sarajevo, Faculty of forestry, p. 147.
- Ballian, D., Memišević Hodžić, M., 2016b. The variability of some morphological characteristics of pedunculate oak (Quercus robur L.) in the south of Herzegovina. Sarajevo, Faculty of Forestry, University of Sarajevo, Faculty of Forestry, p. 191.
- Ballian, D., Murlin, I., Ballian, D., 2016a. Genetic variability of pedunculate oak in the Bosnian provenance test. Poster presentation. Conference Designing Trees for the Future: Data are the key, Brussels.
- Memišević Hodžić, M., Ballian, D., 2019. Growth tendency of Quercus robur L. provenances in Bosnia and Herzegovina provenance test with relation to fixation index, Kastamonu Uni. Orman Fakültesi Dergisi. 19(2):186-196. [CrossRef]
- Memišević Hodžić, M., Ballian, D., 2019. Heterozygosity as a measure of the genetic variability of pedunculate oak (Quercus robur) in the bosnian-herzegovinian provenance test. Genetics & Applications. Vol. 3, No 2, Special edition, Book of abstracts, 1st Congress of Geneticists in Bosnia and Herzegovina with International Participation, Sarajevo, 02-10.04.2019.
- Memišević Hodžić, M., Ballian, D., Kraigher, H., 2019. Research of morphologic features of up to 10-year-old pedunculate oak (Quercus robur L.) in the provenance test in Žepče, Bosnia and Herzegovina, posters presentation XXV IUFRO World Congress 2019 “Forest Research and Cooperation for Sustainable Development”, Curitiba, Brazil, 29 September - 5 October 2019.
- Memišević Hodžić, M., Murlin, I., Ballian, D., 2016. Variability of eight years old plants of pedunculate oak in provenance test Žepče, Bosnia and Herzegovina, In: Proceedings, Natural Resources, Green Technology and Sustainable Development-Green/2, Zagreb, 05.07.2016, Volume: pp. 106-111. [CrossRef]
- Memišević, M., 2010. Unutarpopulacijska i međupopulacijska variabilnost nekih morfoloških karakteristika hrasta lužnjaka (Quercus robur L.) u području Zapadnog Balkana, master thesis, University of Sarajevo, Faculty of forestry, p. 147.
- Oosterbaan, A., Hochbichler, E., Nicolec, V. N., Speecker, H., 2008. Silvicultural principles, phases and measures in growing valuable 11 pp. http://www.valbruni.freiburg.de/ (B) (PDF) Silvicultural principles, goals and measures in growing valuable broadleaved tree species. Available from: https://www.researchgate.net/publication/40801228_Silvicultural_principles_goals_and_measures_in_growing_valuable_broadleaved_tree_species [accessed Nov 20 2019].
- Pintarić, K., 1969. Njegova šuma. Sarajevo.
- Pintarić, K., 1974. Varijacija u inzericiji grana kod ariša (Larix sp.) raznih provenijencija, Šumarski list 5-6: 193-201.
- Višnjić, Ć., 2010. Variabilnost nekih morfoloških svojstava 16 provenijencija evropske buke (Fagus sylvatica L.). Works of the Faculty of Forestry, University of Sarajevo, No 2: 55-70.