Variability of characteristics of Sessile oak (Quercus petraea (Matt.) Liebl) seedlings from the Area of Outstanding Natural Landscape "Avala"

Article *in* Sustainable Forestry Collection · January 2022

DOI: 10.5937/SustFor2285053P

Vladan Popovic
Institute of Forestry

Sanja Jovanović

INSTITUTE OF FORESTRY • BELGRADE
INSTITUT ZA ŠUMARSTVO • BEOGRAD

SUSTAINABLE FORESTRY COLLECTION 85-86, 2022

ODRŽIVO ŠUMARSTVO ZBORNIK RADOVA 85-86, 2022

DOI: 10.5937/SustFor2285053P
Original scientific paper

VARIABILITY OF CHARACTERISTICS OF SESSILE OAK (*Quercus petraea (Matt.) Liebl*) SEEDLINGS FROM THE AREA OF OUTSTANDING NATURAL LANDSCAPE "AVALA"

Vladan POPOVIĆ[1], Aleksandar LUČIĆ[1], Sanja JOVANOVIĆ[1], Ljubinko RAKONJAC[1]

Abstract: *The research of the variability within the population based on morphometric characteristics of seedlings had been conducted to preserve the available gene pool of the Sessile oak population located in the Area of Outstanding Natural Landscape (AONL) "Avala" and the controlled use of the genetic resources.*

Fifty best-quality trees based on the phenotypic characteristics, the carriers of the Sessile oak (Quercus petraea (Matt.) Liebl) reproductive material production were selected at the population level. Approximately 3 kg of apparently healthy and undamaged acorns were collected from each tree, separated by mother trees, and used for seedling production in the nursery under uniform environmental conditions. The root collar diameter and the height of the randomly selected 50 seedlings per half-sib line were measured at the end of the first growing season, and the sturdiness quotient was calculated based on the measured values.

The obtained mean values of the morphometric characteristics indicate a high variability among the tested genotypes. This is also confirmed by the analysis of variance which determined statistically significant differences between the analyzed half-sib lines for all observed morphometric characteristics.

The obtained results represent a good starting point for future research on breeding, long-term preservation, and improvement of the ecological adaptability and evolutionary potential of the Sessile oak population by applying adequate in-situ and ex-situ conservation measures. Based on the research results, it can be recommended to use this

[1]Ph.D. Vladan Popović, Ph.D. Aleksandar Lučić, Senior Research Associate, Senior Research Associate B.Sc. Sanja Jovanović, Junior Researcher, Ph.D. Ljubinko Rakonjac, Principal Research Fellow, Institute of Forestry, Kneza Višeslava 3, Belgrade, Serbia

important species for reintroduction in optimal microclimatic conditions, as well as for the selection of the best individuals for reintroduction.

Key words: seedlings, variability, gene pool, population.

.

VARIJABILNOST SVOJSTAVA SADNICA KITNJAKA (*Quercus petraea (Matt.) Liebl*) SA PODRUČJA PIO „AVALA“

Izvod: *Istraživanje intrapopulacijske varijabilnosti na osnovu morfometrijskih svojstava sadnica sprovedeno je u cilju očuvanja raspoloživog genofonda hrasta kitnjaka u populaciji na području predela izuzetnih odlika Avala i kontrolisanog korišćenja genetičkih resursa.*

Pedeset stabala najboljeg kvaliteta na osnovu fenotipskih karakteristika, nosilaca proizvodnje reproduktivnog materijala hrasta kitnjaka (Quercus petraea (Matt.) Liebl) odabrano je na nivou populacije. Po svakom stablu sakupljeno je oko 3 kg okularno zdravog i neoštećenog žira, od koga su odvojeno po materinskim stablima u rasadniku, u ujednačenim uslovima sredine proizvedene sadnice. Na kraju prvog vegetacionog perioda na slučajnom uzorku od 50 sadnica po liniji polusrodnika mereni su prečnik u korenovom vratu i visina sadnica, a na osnovu izmerenih vrednosti izračunat je koeficijent jedrine.

Srednje vrednosti morfometrijskih karakteristika dobijene u istraživanju ukazuju na visoku varijabilnost među ispitivanim genotipovima. Ovo potvrđuje i analiza varijanse kojom su utvrđene statistički značajne razlike između analiziranih linija polusrodnika za sve posmatrane morfometrijske karakteristike.

Dobijeni rezultati predstavljaju dobru polaznu osnovu za buduća istraživanja oplemenjivanja, dugoročnog očuvanja i unapređenja ekološke prilagodljivosti i evolutivnog potencijala populacije hrasta kitnjaka primenom adekvatnih mera in situ i ek situ očuvanja. Na osnovu rezultata istraživanja mogu se dati preporuke za korišćenje ove značajne vrste u njenoj reintrodukciji u optimalnim mikroklimatskim uslovima, kao i u selekciji najboljih individua za ponovnu reintrodukciju.

Ključne reči: sadnice, varijabilnost, genofond, populacija.

1. INTRODUCTION

The Sessile oak (*Quercus petraea /Matt./ Leibl.*) represents, right after the Pedunculate oak (*Quercus robur*), the most valuable oak species in the growing stock of the Republic of Serbia. Its share in the total volume is 5.9%, that is, it occupies an area of 173.200 ha. Pure stands are represented by 57.5%, mixed stands by 42.5%, while coppice stands are dominant on about 75% of the surface (Banković et al. 2009). The Sessile oak mainly occurs on warmer, southern exposures within the Quercion petraeae-cerris association (Laksh. and Job. 1980). The Sessile oak forests in Serbia are located within a special oroclimatogenic altitudinal zone, above the climatogenic Turkey and Hungarian oak forests. The Sessile oak forest complex includes the upper part of the hill range and the lower mountain range, at an elevation of 300 - 1300 m (Stojanović, Lj., et al., 2005). In the last few decades, the dieback of the Sessile oak stands, groups, and individual trees almost in the entire area have been identified due to causes that have not yet been sufficiently studied and systematized. The occurrence is most likely conditioned by the influence of a complex of factors whose effect is cumulative (Marinković, P., et al., 1990). What is evident is that negative activities in the near and distant past caused major changes in natural ecosystems, which gradually led to the decline of populations, and their habitats were destroyed or reduced (BOROVICS AND MATIAS, 2013; TORRES-RUIZ et al., 2019; ŠIJAČIĆ-NIKOLIĆ et al., 2020). Based on the recent research results achieved related to the phenomenon of Sessile oak dieback, it can be considered that it is a consequence of the following: global climate change, changes in the population structure in the Sessile oak forests, air pollution, plant diseases, insect gradations, etc. (Isaev, V., et al 2005).

Genetic improvement programs include the individual selection of plus trees from the most valuable populations and the testing of their progeny in comparative experiments at different sites (Wright, 1976). The long-term survival of species is closely related to their genetic diversity (Gapare, 2014). Under the influence of changed environmental conditions, biotic agents of disease and damage, the survival and evolution of species depend on the level of genetic diversity (Reed and Frankham, 2003). Genetic diversity research that identifies populations with high genetic variability can help reduce the risk of biodiversity loss (Souto et al., 2015). Determining the level of population variability can be used to provide guidelines and recommendations for the conservation and directed use of genetic resources (Popović et al. 2021a). By combining the knowledge of meteorology, and genetics, and examining phenotypic plasticity, the above-mentioned programs strive to predict the dynamics of species evolution, preserve indigenous species, and select the most resistant and successful individuals. In this respect, Sessile oak is a species of choice for future mixed stands of European forests that will adapt to climate change and survive in dry conditions, and it is expected for this species to increase its share in forest stands (Kohler et al., 2020). Sessile oak trees in the forest ecosystem of the Area of Outstanding Natural Landscape “Avala”, near the capital of Serbia - Belgrade, are exposed to a higher level of human threats, due to their specific location and surroundings (ALVEY, 2006; FAO, 2016). The goals of multipurpose silviculture in special-purpose forests can be achieved by applying close-to-nature silviculture, where the natural site potential is optimally used to preserve their naturalness, biodiversity, and genetic variability, improve the condition, and increase productivity (Stajić et al. 2020).

The research aim was to determine the variability within the Sessile oak population in the Area of Outstanding Natural Landscape “Avala” based on the morphological characteristics of the seedlings. The results obtained in the research can help to get a preliminary understanding of the genetic variability of the studied population and propose measures for the preservation of the available gene pool and improvement of the quality of seed and planting material production.

2. MATERIAL AND METHODS

The one-year-old seedlings produced from acorns collected in 2019 from the Sessile oak test trees in the Area of Outstanding Natural Landscape “Avala” were used for the research presented in this paper. To determine the genetic variability and assess the condition of genetic resources in the Area of Outstanding Natural Landscape "Avala", 50 Sessile oak trees (*Quercus petraea (Matt.) Liebl*) were selected and sampled. Representative, phenotypically best-quality trees, bearers of production of reproductive material in good health were sampled. The trees are evenly distributed over the entire surface of the protected area, at least 50 m apart from each other to avoid relatedness. About 3 kg of apparently healthy and undamaged acorns regardless of dimensions were collected per tree. After the collection, the acorns were dried to 35% moisture content and stored at the temperature of 3-5 ºC. The seeds were collected from the tree to breed the half-sib lines, where the mother is known but not the other parent, according to the method of genetic analysis of the trees (Isajev and Mančić, 2001). Acorns were sown in April 2020, separately by mother trees, in the seedling nursery of the Institute of Forestry in Belgrade. The seedlings were produced in uniform environmental conditions in hotbeds of dimensions 1x50 meters. The row spacing in the hotbed was 15 cm, and the rows were parallel to the shorter side of the hotbed.

Analyzes of measured and derived morphometric characteristics were performed on a random sample of 50 seedlings per mother tree, at the end of the first vegetation season. The root collar diameter and the height of the seedlings were measured and based on the obtained values, the sturdiness quotient was calculated according to Roller 1977. The root collar diameter was measured with a vernier caliper with an accuracy of 0.1 mm, and the seedling height with a ruler with an accuracy of 0.5 cm.

Morphological characteristics of seedlings were described by descriptive statistical indicators: arithmetic means (x), standard deviation (SD), and coefficient of variability (CV %). The analysis of variance (ANOVA) was used to determine the variability within the population. The source of the analyzed variability factors was the tree. All the statistical analyzes were performed by using STATISTICA 7.0 software (StatSoft Inc. 2004).

3. RESULTS AND DISCUSSION

Table 1 shows the parameters of descriptive statistics for the studied seedling characteristics.

The mean value of the seedling root collar diameter is 4.4 mm and it ranges from 3.3 mm (half-sib line 22) to 5.6 mm (half-sib line 41). The mean value of the seedling height is 22.9 cm and it ranges from 12.1 cm (half-sib line 22) to 35.5 cm (half-sib line 47). The mean value of the ratio of height to root collar diameter of seedlings is 5.3 and it ranges from 3.4 (half-sib line 19) to 7.5 (half-sib line 46). The mean value of the coefficient of variability for the root collar diameter of seedlings is 25.1% and it ranges from 12.7% (test tree 10) to 47.3% (test tree 28). The mean value of the coefficient of variability for seedling height is 35.6% and it ranges from 19.1% (test tree 9) to 60.4% (test tree 37). The mean value of the coefficient of variability for the sturdiness quotient according to Roller is 33.2% and it ranges from 16% (test tree 47) to 68.1% (test tree 28).

The most variable characteristic at the level of the studied half-sib lines is the seedling height (35.6%), while the root collar diameter is the least variable characteristic (25.1%).

Table 1. *Descriptive statistics for the measured morphological characteristics of the seedlings*

Tree	d (mm)					h (mm)					h/d				
	M	SD			CV	M	SD			CV	M			SD	CV
1	3.6	2.5	8.1	1.2	32.4	25.5	13.0	38.0	6.2	24.2	7.3	3.7	10.8	1.9	26.5
2	5.1	3.8	7.1	1.0	19.1	23.9	15.0	36.5	6.6	27.7	4.8	3.1	8.4	1.5	30.8
3	3.9	2.1	6.4	1.1	29.0	20.7	13.0	32.5	5.1	24.7	5.6	4.0	9.0	1.3	22.8
4	4.6	3.4	6.0	0.8	17.1	21.2	10.0	34.0	6.2	29.2	4.7	2.5	7.6	1.3	28.1
5	4.3	2.6	6.5	0.9	21.8	21.4	13.0	38.0	6.7	31.3	5.1	2.6	8.6	1.7	33.8
6	4.5	3.4	6.1	0.8	17.4	22.5	8.0	33.5	6.7	29.8	5.0	2.3	8.6	1.4	27.9
7	5.0	2.5	7.9	1.5	29.1	23.5	15.0	45.5	8.4	35.8	4.9	2.3	7.4	1.6	31.9
8	4.6	2.9	6.0	0.8	16.5	23.8	7.5	36.5	8.8	37.0	5.1	1.6	7.5	1.7	33.6
9	4.2	2.2	5.4	0.9	21.4	25.1	18.0	36.0	4.8	19.1	6.4	4.6	13.2	2.2	34.8
10	4.9	3.8	5.9	0.6	12.7	22.9	13.0	35.0	6.2	27.2	4.7	2.8	6.9	1.2	25.7
11	4.5	2.6	6.0	1.0	21.3	24.7	12.0	35.0	5.6	22.5	5.6	3.2	8.8	1.5	26.0
12	4.4	3.0	6.5	1.1	25.1	24.1	10.0	42.5	8.8	36.5	5.6	2.2	9.6	1.8	31.9
13	3.6	2.2	5.3	0.9	24.3	18.1	9.0	30.0	6.3	34.9	5.1	2.7	8.3	1.4	27.9
14	3.9	2.8	5.5	0.8	20.7	17.5	6.5	31.0	7.5	42.8	4.4	2.0	7.3	1.5	33.9
15	4.6	1.8	7.5	1.3	28.3	18.6	10.0	29.0	6.1	32.7	4.2	2.0	6.8	1.3	30.9
16	4.0	2.3	5.2	0.7	17.7	17.9	7.0	37.5	8.5	47.4	4.5	1.8	8.6	1.9	42.4
17	4.9	3.2	6.7	1.1	22.6	26.2	11.0	51.0	9.2	35.2	5.7	2.2	9.5	2.4	41.0
18	4.9	3.5	6.5	1.0	19.6	23.3	13.0	41.0	7.5	32.1	4.9	2.8	7.8	1.5	30.9
19	3.7	2.4	5.1	0.8	21.5	12.5	4.0	30.0	6.6	52.5	3.4	1.4	6.5	1.5	45.0
20	3.9	2.6	5.5	0.8	21.4	15.0	7.5	27.0	5.5	36.8	3.9	1.9	6.5	1.2	29.9
21	3.8	2.0	5.9	1.1	28.0	17.1	7.0	27.5	5.7	33.5	4.7	2.6	7.5	1.6	34.6
22	3.3	2.2	4.6	0.8	25.0	12.1	6.0	30.0	5.7	47.4	3.7	1.7	6.8	1.1	29.5
23	3.8	2.2	6.5	1.3	32.9	17.4	8.0	34.5	8.0	45.8	4.6	2.4	6.6	1.2	26.9
24	3.3	2.1	4.7	0.8	23.4	13.1	6.0	20.0	4.0	30.4	4.1	1.9	6.2	1.2	29.8
25	3.5	2.2	5.4	0.7	20.0	15.4	7.0	27.0	5.5	35.6	4.6	1.9	9.2	1.9	40.5
26	4.1	2.6	6.0	0.8	20.1	18.2	6.0	28.0	5.8	31.7	4.5	1.5	6.9	1.2	27.6
27	4.0	1.4	6.1	1.3	32.3	15.0	8.0	27.5	5.6	37.2	4.0	1.4	7.4	1.5	38.1
28	3.9	1.2	7.8	1.8	47.3	22.4	10.0	43.0	9.7	43.3	7.0	2.7	19.8	4.8	68.1
29	4.7	2.5	7.8	1.4	29.1	22.1	11.0	42.5	8.9	40.4	4.7	2.6	7.0	1.2	25.4
30	4.2	1.9	6.1	1.1	27.1	20.7	7.5	33.0	6.9	33.5	5.0	3.1	7.9	1.2	23.8
31	4.6	1.3	8.2	1.7	36.2	21.7	7.0	51.5	10.9	50.4	5.2	1.8	15.9	3.2	61.8
32	3.6	1.3	6.3	1.4	39.5	19.2	9.0	36.5	7.4	38.7	6.2	2.6	14.2	3.6	58.6
33	4.5	3.0	6.5	0.9	19.0	21.8	12.0	33.0	4.8	22.1	5.0	2.7	8.1	1.5	29.3
34	4.0	2.5	5.8	1.0	24.9	21.2	8.0	45.0	9.3	44.0	5.2	2.2	8.0	1.4	27.0
35	4.7	3.1	6.9	0.9	19.6	26.9	10.0	47.5	12.3	45.6	5.5	2.4	8.9	1.8	33.3
36	4.5	2.9	7.0	1.1	24.1	25.3	10.0	61.0	12.0	47.5	5.6	2.3	8.7	1.9	34.2
37	4.3	2.4	7.0	1.1	26.2	20.4	7.5	48.0	12.3	60.4	4.6	1.9	7.8	2.0	43.1
38	4.6	2.5	7.9	1.3	28.1	21.9	10.0	38.0	6.4	29.2	5.0	1.8	10.1	1.9	38.2
39	5.3	3.6	7.0	1.0	19.4	23.3	7.5	39.5	9.4	40.4	4.4	1.9	7.0	1.5	33.4
40	4.9	3.5	6.8	0.9	19.0	24.5	9.0	43.5	9.8	39.9	4.9	2.0	7.5	1.4	29.3
41	5.6	3.1	9.1	1.4	25.3	33.3	13.0	44.0	8.4	25.3	6.1	2.6	8.4	1.3	21.9
42	5.6	3.3	13.6	2.1	37.5	26.0	13.0	41.0	9.3	35.9	4.9	1.6	8.2	1.7	34.6
43	4.9	2.7	8.1	1.5	30.2	26.3	9.0	44.5	10.6	40.3	5.4	2.5	8.3	1.6	30.4
44	5.4	3.9	6.7	0.9	17.1	32.1	14.5	48.5	10.9	34.1	5.9	3.6	9.5	1.6	26.7
45	4.9	2.6	8.7	1.4	27.5	29.7	12.5	56.0	14.2	48.0	6.0	2.7	10.0	2.3	38.6
46	4.5	1.4	7.3	1.5	32.6	31.6	20.0	45.5	7.8	24.7	7.5	4.5	15.6	2.6	34.1
47	5.4	3.5	8.8	1.3	23.2	35.5	25.0	60.0	8.3	23.4	6.7	4.5	8.8	1.1	16.0
48	5.2	2.1	7.6	1.3	25.8	34.2	13.5	51.0	10.8	31.6	6.7	3.7	10.5	1.8	26.8
49	4.8	2.8	8.5	1.4	28.1	33.3	14.5	56.5	10.6	32.0	7.1	3.5	14.4	2.3	32.2
50	4.7	1.8	6.3	1.2	26.3	32.8	18.0	52.0	9.8	29.8	7.3	5.1	13.3	2.2	30.5
Mean	4.4	2.6	6.8	1.1	25.1	22.9	10.7	39.5	8.0	35.6	5.3	2.6	9.1	1.7	33.2

Note: d-root collar diameter; h- seedling height; h/d-height: root collar diameter ratio

Table 2. *Analysis of variance for the measured morphological characteristics of the seedlings*

Parameter	SS Effect	df Effect	MS Effect	F	p
d	49	347.33	7.09	5.41	0.0000
h	49	32084.4	654.8	9.521	0.0000
h/d	49	946.07	19.31	5.519	0.0000

To confirm the existence of a satisfactory level of genetic variability, the one-way analysis of variance (ANOVA) was performed based on the measured values, where the source of variability was the test tree. The results of the conducted analysis show that the trees within the population differ significantly at the significance level of $p<0.01$ for all observed morphological characteristics of seedlings (Table 2).

The existence of statistically significant differences between the studied half-sib lines for all analyzed morphological characteristics of seedlings indicates genetic differentiation and a high degree of variability within the population. Based on the obtained statistical parameters, it can be confirmed the existence of genetic variability both within and between the analyzed half-sib lines. The analyzed seedling characteristics are quantitative and controlled by polymer genes whose effects are added together. The variability of quantitative characteristics is wide and has a continuous character, and it is conditioned by the interaction of polymeric genes and environmental factors. The occurrence of a high degree of variability within the population is characteristic of most species of forest trees and can be explained by the process of gene migration and a low degree of local adaptation (Bogdan, S., 2009). As the presented results confirm the assumption of high variability within the population, the very population can be used in breeding processes and as a potential source of quality reproductive material. Statistically significant differences determined between individual parent trees (genotypes) in the analysis of morphological characteristics of acorns (Popović et al. 2021b) and morphological characteristics of leaves (Popović et al. 2020) also indicated a high level of genetic diversity within the population. A high level of genetic diversity was determined between the analyzed trees in this population of Sessile oak by using seven SSR markers (Popović et al. 2022).

A prerequisite for the successful preservation and improvement of the gene pool of forest woody species is knowledge of genetic diversity and population structure. For the survival and stability of populations, adequate ecological management is necessary with the aim of preservation and implementation of *in situ* conservation measures, along with monitoring and improving genetic diversity (Bruschi et al. 2003). Considering climate change, the adaptive potential of forest tree populations is largely determined by individual levels of relatedness (Lloret and García. 2016). The long-term survival of populations and losses of genetic resources are threatened by uncontrolled logging and the irrational use of resources (Gilpin and Soule. 1986). The reduction of populations leads to the decline of genetic diversity and the appearance of inbreeding, which in the long run can affect the reduction of heterozygosity and stability. Gene flow between and within populations depends on the orographic habitat conditions, the degree of population isolation, and the movement of pollen and seeds (Bruschi et al. 2003). Populations showing tolerance to drought stress, genetically improved, will be very important in the future to deal with the consequences of climate change (Apostol et al. 2020).

Based on the conducted research, it can be concluded that there is a high level of variability in the observed morphological characteristics of seedlings of the studied Sessile oak population. The obtained results are the basis for the continuation of the research that needs to be carried out to provide guidelines and recommendations for the conservation and directed use of genetic resources.

4. CONCLUSION

The results obtained in this research showed a high level of genetic variability at the level of the studied population. Satisfactory genetic diversity recommends this population for the dynamic conservation of Sessile oak genetic resources in Serbia. To provide additional security for the preservation of the gene pool, the establishment of *ex situ* conservation facilities is recommended. Considering the pronounced genetic variability, it can be assumed that the studied population has resistance to deterioration and adaptive potential in terms of changes caused by climatic conditions.

The determined variability of the seedlings' morphological characteristics can serve as an indicator of the further development of the selected half-sib lines' seedlings and can be useful for the improvement of the production of high-quality Sessile oak seed material.

The measures that would ensure the natural regeneration of the Sessile oak natural populations with constant monitoring of the genetic structure and timely implementation of measures to maintain natural genetic diversity should be included in the management of the Sessile oak natural populations.

Acknowledgments: *This study was carried out under the Agreement on realization and funding of scientific research activity of scientific research organizations in 2022 funded by the Ministry of Education. Science, and Technological Development of the Republic of Serbia. No. 451-03-68/2022-14/ 200027 from February 04, 2022.*

REFERENCES

Apostol, E.N., Stuparu, E., Scarlatescu, V., Budeanu, M. (2020): Testing Hungarian oak (*Quercus frainetto* Ten.) provenances in Romania. iForest. 13: 9-15.

Banković, S., Medarević, M., Pantić, D., Petrović, N., Šljukić, B., Obradović, S. (2009): Growing stock of the Republic of Serbia – condition, and issues. Bulletin of the Faculty of Forestry No. 100, p. 7-30, Belgrade. (Original title: Шумски фонд Републике Србије - стање и проблеми. Гласник шумарског факултета бр. 100, стр. 7-30, Београд.

Bogdan, S. (2009): Genetics with tree and shrub breeding (internal script). Faculty of Forestry, University of Zagreb, 1-207. (Original title: Genetika s oplemenjivanjem drveća i grmlja (interna skripta). Šumarski fakultet Sveučilišta u Zagrebu, 1-207).

Borovics, A., Mátyás, C. (2013): Decline of genetic diversity of sessile oak at the retracting (xeric) limits. Annals of Forest Science 70(7): 835-844. DOI 10.1007/s13595-013-0324-6

Bruschi, P., Vendramin, G., Bussotti, F., Grossoni, P. (2003): Morphological and Molecular Diversity Among Italian Populations of *Quercus petraea* (*Fagaceae*). Annals of Botany 91: 707-716.

Gapare, W.J. (2014): Merging applied gene conservation activities with advanced generation breeding initiatives: a case of study of Pinus radiate D. Don. New For. 45: 311–331.

Gilpin, M.E., Soule, M.E. (1986): Minimum viable populations processes of species extinctions. In: Soule ME. ed.Conservation biology: the science of scarcity and diversity. Sunderland: Sinauer. 19-34.

Isajev, V., Mančić, A. (2001): Forest seed production. Faculty of Forestry. University of Banja Luka. University of Belgrade - Faculty of Forestry. Banja Luka. Belgrade (1-283). (Original Title: Šumsko semenarstvo. Šumarski fakultet. Univerziteta u Banja Luci. Univerzitet u Beogradu - Šumarski fakultet. Banja Luka. Beograd (1-283)).

Isajev, V., Ivetić, V., Vukin, M. (2005): Artificial regeneration of Sessile oak forests, Forestry 3. Association of Forestry Engineers and Technicians of Serbia, 37-51. (Original Title: Вештачко обнављање шума храста китњака, Шумарство 3. Удружење шумарских инжењера и техничара Србије, 37-51).

Kohler, M., Pyttel, P., Kuehne, C. (2020): On the knowns and unknowns of natural regeneration of silviculturally managed sessile oak (Quercus petraea (Matt.) Liebl.) forests—a literature review. Annals of Forest Science 77, 101. https://doi.org/10.1007/s13595-020-00998-2

Lloret, F., García, C. (2016): Inbreeding and neighbouring vegetation drive drought induced die off within juniper populations. Functional Ecology. Vol. 30. No. 10: 1696-1704.

Marinković, P., Popović, J., Karadžić, D. (1990): Causes of epidemic oak dieback, importance and possibilities of remediation of infection hotspots, Šumarstvo 2-3. Thematic number "Drying of forests", 7-17. (Original Title: Узроци епидемијског сушења храста, значај и могућности санирања жаришта заразе, Шумарство 2-3. Тематски број „Сушење шума“, 7-17).

Popović, V., Daničić, V., Milovanović, J., Lučić, A., Rakonjac, Lj., Mladenović Drinić, S., Ristić, D. (2022). Genetic structure of Sessile oak (Quercus petraea (Matt.) Liebl) from the Area of Outstanding Natural Beauty “Avala“, Genetika, Vol 54, No2, 841-856.

Popović, V., Lučić, A., Rakonjac, Lj., Hadrović, S. (2020): Variability of the Sessile oak (Quercus petraea (Matt.) Liebl) in the Area of Outstanding Natural Landscape (AONL) “Avala” based on the morphological characteristics of the leaves. Forestry 3-4. Association of Forestry Engineers and Technicians of Serbia. p. 1-10. ISSN 0350-1752. (Original Title: Varijabilnost hrasta kitnjaka (Quercus petraea (Matt.) Liebl) na području PIO „Avala“ prema morfološkim svojstvima listova. Šumarstvo 3-4. Udruženje šumarskih inženjera i tehničara Srbije. p. 1-10. ISSN 0350-1752).

Popović, V., Lučić, A., Rakonjac, Lj., Jovanović, S., Lazarević, I. (2021a): Variability of Hungarian oak (*Quercus frainetto* Ten.) from the territory of Lipovica according to morphological traits of seedlings. Sustainable Forestry, 83-84, 27-36.

Popović, V., Lučić, A., Jovanović, S., Rakonjac, Lj. (2021b): Variability of morphometric characteristics of sessile oak (Quercus petraea (Matt.) Liebl) acorn). XII International Scientific Agriculture Symposium “AGROSYM 2021”. Jahorina, October 07 – 10. 2021. Pp. 1414-1420. ISBN 978-99976-787-9-9.

Reed, D.H., Frankham, R. (2003): Correlation between fitness and genetic diversity. Conserv. Biol. 17: 230–237.

Roller, K.J. (1977): Suggested minimum standards for containerized seedlings in Nova Scotia. Department of Fisheries and Environment Canada. Canadian Forestry Service. Information Report M-X-69 (1-18)

Souto, C., Mathiasen, P., Acosta, M. (2015): Identifying genetic hotspots by mapping molecular diversity of widespread trees: when commonness matters. J. Hered. 106: 537–545.
Wright. J.W. (1976): Introduction to forest genetics. Academic Press. New York. USA. pp. 463.

Stajić, S., Čokeša, V., Miletić, Z., Eremija, S., Ćirković-Mitrović, T., Marković, M., Jovanović, F. (2020): Phytosociological characteristics of sessile oak and hornbeam forests (Querco petraeae-carpinetum betuli Rudski 1949. s.l.) in the area of Kosmaj (2008): Sustainable Forestry. 81-82. 41-52

StatSoft Inc., 2004. STATISTICA. version 7.

Stojanović, Lj., Krstić, M., Bjelanović, I. (2005): Thinning in the Sessile oak forests of Northeastern Serbia, Forestry 3. Association of Forestry Engineers and Technicians of Serbia, 1-24. (Original Title: Проредне сече у шумама храста китњака на подручју североисточне Србије, Шумарство 3. Удружење шумарских инжењера и техничара Србије, 1-24).

Torres-Ruiz J.M., Kremer, A., Carins Murphy, M.R., Brodribb, T., Lamarque, L.J., Truffaut, L., Bonne, F., Ducousso, A., Delzon, S. (2019): Genetic differentiation in functional traits among European sessile oak populations, Tree Physiology, 39(10): 1736–1749. https://doi.org/10.1093/treephys/tpz090

Šijačić-Nikolić, M., Milovanović, J., Nonić, M., Ivetić, V., Popović, V., Lučić, A. (2020): The Second Report on the State of the World’s Forest Genetic Resources: Serbia. The Republic of Serbia. Ministry of agriculture, forestry and water management and the University of Belgrade- Faculty of Forestry (in press).

VARIABILITY OF CHARACTERISTICS OF SESSILE OAK (*Quercus petraea (Matt.) Liebl*) SEEDLINGS FROM THE AREA OF OUTSTANDING NATURAL LANDSCAPE “AVALA”

Vladan POPOVIĆ, Aleksandar LUČIĆ, Sanja JOVANOVIĆ, Ljubinko RAKONJAC

Summary

The Sessile oak (*Quercus petraea /Matt./ Leibl.*) represents, right after the Pedunculate oak (*Quercus robur*), the most valuable oak species in the growing stock of the Republic of Serbia. Its share in the total volume is 5.9%, that is, it occupies an area of 173.200 ha. The Sessile oak forests are located within a special oroclimatogenic altitudinal zone, above the climatogenic Turkey and Hungarian oak forests and cover the upper part of the hill range and the lower mountain range, at an elevation of 300 - 1300 m). In the last few decades, the dieback of the Sessile oak stands, groups, and individual trees almost in the entire area have been identified due to causes that have not yet been sufficiently studied and systematized.

The research aim was to determine the variability based on morphometric characteristics of seedlings within the Sessile oak population located in the Area of Outstanding Natural Landscape (AONL) “Avala”. The results obtained in the research can help to get a preliminary understanding of the genetic variability of the studied population and propose measures for the preservation of the available gene pool and improvement of the quality of seed and planting material production.

The one-year-old seedlings produced from acorns collected in 2019 from the 50 Sessile oak test trees in the Area of Outstanding Natural Landscape “Avala” were used for the research presented in this paper. Analyzes of measured and derived morphometric characteristics were performed on a random sample of 50 seedlings per mother tree, at the end of the first vegetation season. The root collar diameter and the height of the seedlings were measured and based on the obtained values, the sturdiness quotient was calculated.

The following mean values were obtained at the level of the studied half-sib lines: the mean value of the seedling root collar diameter is 4.4 mm and it ranges from 3.3 mm to 5.6 mm; the mean value of the seedling height is 22.9 cm and it ranges from 12.1 cm to 35.5 cm; the mean value of the ratio of height to root collar diameter of seedlings is 5.3 and it ranges from 3.4 to 7.5. The existence of statistically significant differences between the studied half-sib lines for all analyzed morphological characteristics of seedlings indicates genetic differentiation and a high degree of variability within the population. Based on the obtained statistical parameters, it can be concluded that there is genetic variability both within and between the analyzed half-sib lines.

Results obtained in this study showed a high level of genetic variability in the researched population. Satisfactory genetic diversity recommends this population for the dynamic conservation of genetic resources of the Sessile oak in Serbia. To provide additional security for the preservation of the gene pool, the establishment of ex situ conservation facilities is recommended. Considering the pronounced genetic variability, it can be assumed that the studied population has resistance to deterioration and adaptive potential to changes caused by climatic conditions.

VARIJABILNOST SVOJSTAVA SADNICA KITNJAKA (*Quercus petraea (Matt.) Liebl*) SA PODRUČJA PIO „AVALA“

Vladan POPOVIĆ, Aleksandar LUČIĆ, Sanja JOVANOVIĆ, Ljubinko RAKONJAC

Rezime

U šumskom fondu Republike Srbije, kitnjak (*Quercus petraea /Matt./ Leibl*.) posle lužnjaka predstavlja najvredniju vrstu hrasta. U ukupnoj zapremini učestvuje sa 5,9%, odnosno zauzima površinu od 173.200 ha. Šume kitnjaka u nalaze se u okviru posebnog oroklimatogenog visinskog pojasa, iznad klimatogene šume sladuna i cera, obuhvataju gornji deo brdskog pojasa i niži planinski pojas, na nadmorskim visinama od 300 – 1300 m. U poslednjih nekoliko decenija sastojine, grupe i pojedinačna stabla kitnjaka gotovo na čitavom arealu se suše iz do sada još uvek nedovoljno proučenih i sistematizovanih uzroka.

Cilj istraživanja u ovom radu bio je da se utvrdi unutarpopulaciona varijabilnost kitnjaka u populaciji na području PIO „Avala“ prema morfološkim svojstvima sadnica. Dobijeni rezultati u istraživanju mogu da posluže za preliminarno upoznavanje genetičkog varijabiliteta proučavane populacije, prelog mera očuvanja raspoloživog genofonda i za unapređenje proizvodnje kvalitetnog semenskog i sadnog materijala.

Za istraživanja u ovom radu upotrebljene su jednogodišnje sadnice proizvedene od žira iz uroda 2019. godine, sakupljenog sa 50 test stabala kitnjaka u PIO „Avala“. Analize merenih i izvedenih morfometrijskih svojstava vršene su na slučajnom uzorku koji je činilo 50 sadnica po svakom materinskom stablu, na kraju prvog vegetacionog perioda. Mereni su prečnik u korenovom vratu i visina sadnica, a na osnovu izmerenih vrednosti izračunat je koeficijent jedrine.

Na nivou istraživanih linija polusrodnika dobijene su sledeće prosečne vrednosti: prečnik u korenovom vratu iznosi 4,4 mm (od 3,3 do 5,6 mm), visina sadnica iznosi 22,9 cm (od 12,1 do 35,5 cm), koeficijent jedrine sadnica iznosi 5,3 (od 3,4 do 7,5). Postojanje statistički značajnih razlika između proučavanih linija polusrodnika za sva analizirana morfološka sadnica, jasno ukazuju na genetsku diferencijaciju i visok stepen unutarpopulacione varijabilnosti. Na osnovu dobijenih statističkih parametara može se zaključiti da postoji genetička promenljivost kako unutar, tako i između analiziranih linija polusrodnika.

Rezultati dobijeni u ovom istraživanju pokazali su visok nivo genetske varijabilnosti na nivou istraživane populacije. Zadovoljavajući genetski diverzitet preporučuje ovu populaciju za dinamično očuvanje genetičkih resursa kitnjaka u Srbiji. U cilju dodatne sigurnosti očuvanja genofonda preporučuje se uspostavljanje ex situ objekata konzervacije. S obzirom na izraženu genetsku varijabilnost, može se pretpostaviti da proučavana populacija ima otpornost na propadanje i adaptivni potencijal u pogledu promena izazvanih klimatskim uslovima.