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SELECTION OF SESSILE OAK (*Quercus petraea* (Matt.) Liebl.) PLUS TREES FOR SEED ORCHARD ESTABLISHMENT

Vladan POPOVIĆ[1], Sanja LAZIĆ[1], Aleksandar LUČIĆ[1], Ljubinko RAKONJAC[1], Radojica PIŽURICA[1], Boris IVANOVIĆ[2], Aleksandra PETROVIĆ[2]

Abstract: *The results of selection of plus trees of sessile oak (Quercus petraea (Matt.) Liebl.) as a base for establishing a seed orchard are presented in this paper. The research included 86 trees of phenotypically highest quality, selected based on morphological and physiological criteria, in order to preserve and improve the genetic diversity of the species. Morphological characteristics of leaves and acorns were analysed, including dimensions, mass and the ratio of certain parameters. The results of one-way analysis of variance showed that there are statistically significant differences among the trees for all observed characteristics (p < 0.01), which indicates a high level of genetic and morphological variability. The obtained results confirm that selected plus trees represent a suitable source of reproductive material for establishment of seed orchard of sessile oak. This way a basis for long-term conservation of genetic potential and adaptive capacity of the species is created.*

Keywords: *Quercus petraea*, plus trees, morphological variability, acorn, leaf, seed orchard, genetic diversity.

SELEKCIJA PLUS STABALA HRASTA KITNJAKA (*Quercus petraea* (Matt.) Liebl.) ZA POTREBE OSNIVANJA SEMENSKE PLANTAŽE

Sažetak: *U ovom radu prikazani su rezultati selekcije plus stabala hrasta kitnjaka (Quercus petraea (Matt.) Liebl.) kao osnova za podizanja semenske plantaže. Istraživanja su obuhvatila 86 fenotipski najkvalitetnijih stabala, izdvojenih na osnovu morfoloških i fizioloških kriterijuma, u cilju očuvanja i unapređenja genetičke raznovrsnosti vrste. Analizirane su morfološke karakteristike listova i žira, uključujući dimenzije, masu i odnos pojedinih parametara. Rezultati jednofaktorijalne analize varijanse pokazali su postojanje statistički značajnih razlika među stablima za sva posmatrana svojstva (p < 0,01), što ukazuje na visok nivo genetičke i morfološke varijabilnosti. Dobijeni rezultati potvrđuju da izdvojena plus stabla predstavljaju pogodan izvor reproduktivnog materijala za osnivanje semenske plantaže hrasta kitnjaka, čime se stvara osnova za dugoročno očuvanje genetičkog potencijala i adaptivnog kapaciteta vrste.*

Ključne reči: *Quercus petraea*, plus stabla, morfološka varijabilnost, žir, list, semenska plantaža, genetička raznovrsnost.

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1. INTRODUCTION

Sessile oak (*Quercus petraea* (Matt.) Liebl.) is an autochthonous European species from the most significant group of broadleaved trees. In addition to pedunculate oak and cork oak it represents economically the most significant species of the genus, known for high-quality technical wood of high endurance. In an environmental sense, sessile oak increases forest biodiversity; it is an edifier of numerous types of forests, providing habitat and food for various species of insects, birds and mammals, mosses, as well as microorganisms. Given that the habitats of sessile oak are characterised by somewhat drier conditions, it is considered that its range will expand in the future (Girard et al., 2022), as well as that it is a species of choice in afforestation, in altered climatic conditions of the environment (Lindner et al., 2014; Schelhaas et al., 2015). In this regard it should also be noted that mixed forests of sessile oak are more resistant to fires, and sessile oak itself is considered a species relatively resistant to storms (lightnings and thunders), drought and heat (Kohler et al., 2020; Perkins et al., 2018; Kunz et al., 2018; Modrow et al., 2020).

Due to its importance, sessile oak is one of the two oak species most commonly produced in nurseries in Serbia (Popović et al., 2019). Sessile oak forests occupy 7.84 % of total forest area in the Republic of Serbia (Cuchietti et al., 2023). Since the mid-20th century there has been the trend of die-back of sessile oak, as a consequence of action of multiple factors (monograph on sessile oak). Therefore, restoration of sessile oak forests and their transformation from sprout forests to high forests is one of the most important tasks and goals of forestry in Serbia. However, considering that sessile oak is a species with irregular seed yield, it is necessary to provide sufficient quantities of high-quality seed also during the years without a rich yield.

For these purposes, a necessary prerequisite is the existence of seed orchards which will provide the necessary starting point – high-quality reproductive material of adequate genetic, physiological and morphological characteristics. When establishing seed orchards, superior, plus trees which possess the desired morphological characteristics are selected, while taking care to preserve genetic variability, and use provenances of the given/target region. The existence of genetic diversity, as evidenced by the variability of morphological characteristics, represents the imperative, for the stability and survival of a population, as well as the possibility for adaptation in different environmental conditions, thereby increasing evolutive potential (Alfaro et al., 2014). Selection of plus trees is carried out based on the phenotypic characteristics, which develop through the co-interaction of genotype and environmental conditions (EUFORGEN, 2023). Some of the desired characteristics are physiological vitality, correct tree shape, proportionate crown, fullness of bole, good health, and satisfactory seed production. Some of the listed traits are heritable and, therefore, important for the technical application of wood and its use in various types of industry and production. Also, correlations are shown in some morphological characteristics of trees. For example, Dobrosavljević et al. (2022) showed that the diameter of a sessile oak tree is positively correlated with the number of acorns per m2. This is a consequence of the increase in crown area which increases with the increase of tree diameter (Bechtold 2003). The same study also established the link between larger tree diameter and with larger acorn length and diameter, which in some studies has been associated with larger seedlings (Roth et al., 2009).

Continuing with the above, the link between morphological parameters of acorns and later development of seedlings is known in science. Various studies have shown a positive impact of the acorn size on their germination, rate of aboveground part development, survival success, biomass and overall seedling quality (Roth et al., 2009; Ivankovic et al., 2011). Acorn dimensions also affect the manipulation of this reproductive material in forest nurseries during seedling production, determining the density and depth of planting. (Major 2002).

The leaf, as the main photosynthetic organ is very important for the development and progress of sessile oak and it shows great variability in morphological parameters. They are also used for taxonomic purposes, in distinguishing species, like sessile oak and pedunculate oak, which are prone to mutual hybridization. The basic division of leaves is into heliomorphic (sun leaves) and sciomorphic (shade leaves) which are clearly, morphologically, anatomically and functionally different. The variability of leaf morphological parameters is influenced by genetics, origin, available sunlight, water availability, temperature, phases of polycyclic growth of shoot and leaves. Oaks are characterised by great plasticity and according to Arab et al. (2020) the environmental conditions take precedence over genetic traits and origin when varying morphological parameters, indicating great potential in adapting to current and future environmental conditions, especially in the context of climate change (Arab et al., 2021).

The object of this research was to identify and rate sessile oak plus trees based on the phenotypic traits and morphological characteristics of leaves and seeds, with the aim of selecting the most suitable individuals for establishing a seed orchard.

2. MATERIAL AND METHODS

Site and selection of plus trees

The research was carried out within several forest management units in the territory of natural stands of sessile oak (*Quercus petraea* (Matt.) Liebl.). A total of 86 plus trees were selected and rated as phenotypically of the highest quality. The selection criteria included: good physiological vitality, regular form of the tree, high-quality and proportionate crown, fullness of bole, health condition without the symptoms of disease, and satisfactory seed production. Attention is also paid to spatial arrangement, so that the trees were positioned at least 50 m apart to avoid close relatedness. All selected trees were evaluated according to the following mensurational indicators: diameter at breast height (cm), main stem height (m) and length (m), as well as according to the criteria of the stem form quality and crown form quality, fullness of bole, twisting of the main stem and health condition.

Geographical positioning

All selected plus trees were recorded in space by reading of geographical coordinates and altitude. The obtained data were used for cartographic representation of tree distribution and they form the basis for further monitoring and management of selected genetic resources.

Mensurational parameters and quality assessment

The following basic mensurational indicators were measured for all selected plus trees: diameter at breast height, total height and main stem length. In addition, the method of quality assessment of plus trees in the field was applied, which includes assessing the stem form quality (5 Excellent. Straight stem, apical domination, without strong competitive branches in the top; 4 Good. Weaker apical domination and/or single curved stem; 3 Less good. Bad apical domination and/or more then one stem curve. Fork in upper 2/3 of the tree height; 2 Bad. Very weak apical domination, more then two curves. Low fork (below 2/3 of the tree height) or multiple forks), crown form quality (5 Excellent. Relatively thin branches with flat insertion angle (>60°). Fairly symetrical crown; 4 Good. No more then one thich branch and/or smaller insertion angle (45-60°); Less fairly symmetrical; 3 Less good. More then one thich branches. Acute insertion angle (<45°). Asymetrical and/or not properly developed; 2 Bad. Multiple forks, acute branch insertion angle. Weakly developed and/or extremly asymmetrical), fullness of bole (5 Excellent. Very low degree of taper, very small decrease of diameter as a function of stem height, 3 Good. Moderate degree of taper, 1 Bad. High degree of taper), twisting of main stem (5 no bark twisting, 1 visible bark twisting) and health condition (5 Completely healthy tree without any visible symptoms, 1 Unhealthy. Visible sypmtoms such as cankers, many epicormics, stem cracks, less foliage etc). The data were recorded in standardized forms and used for further selection.

Collection of biological material

From all selected plus trees leaves and acorns were collected. The leaves were collected in the stage of full development, from short fertile shoots of the outer part of the crown, and exclusively from the southeast side in order to ensure comparability of the samples. Between 60 and 70 fully developed, undamaged leaves were collected from each tree, which were herbarized after collection. About 5 kg of ocularly healthy acorns were collected from each plus tree, and a random sample of 50 acorns per plus tree was taken for the purposes of morphometric analyses.

Morphometric measurement

Scanned leaves were measured by LAMINA software tool (Bylesjö et al., 2008). The following parameters were measured on the leaves: leaflet area, circumference, maximum width, width at 25%, 50% and 75% of leaflet length, total leaflet length, length at 25%, 50% and 75% of leaflet width, length-to-width ratio, and petiole length.

The following measurements were made on acorns: length, diameter (width) and mass. Length and diameter were determined by vernier caliper with a precision of 0.01 mm, while mass was measured by analytical scale with a precision of 0.01g.

Statistical processing of data

Basic indicators of descriptive statistics (mean value, minimum, maximum, standard deviation and coefficient of variation) were calculated for all measured parameters. In order to determine the existence of statistically significant differences among plus trees, a one-way analysis of variance (ANOVA) was applied, where a tree was treated as a factor of variability. The level of significance was set on $p<0.01$.

3. RESULTS

Selection and quality assessment of plus trees

All parameters showed that the selected trees meet the criteria of plus trees, which makes them suitable sources of production of reproductive material of the highest quality (Table 1).

Table 1. *Mensurational and quality assessment data of plus trees*

Plus tree ordinal number	Diameter at breast height (cm)	Height (m)	Main stem length (m)	Stem form quality	Crown form quality	Fullness of bole	Twisting of main stem	Health condition
1	40	20.3	8.1	5	4	5	5	5
2	44.5	19.6	7.3	5	5	5	5	5
3	49	19.7	7.8	5	4	5	5	5
4	45.5	22.2	9.7	5	4	5	5	5
5	50	21.4	8.4	5	5	5	5	5
6	41	21.2	10.7	5	5	5	5	5
7	43	22.8	9.2	5	5	5	5	5
8	49	27.5	10.9	5	5	5	5	5
9	42.5	19.7	9.7	5	5	5	5	5
10	40.5	23.3	9.9	5	4	5	5	5
11	45	21.1	8.3	5	4	5	5	5
12	51	24.3	11.5	5	4	5	5	5
13	54.5	20.6	10.4	5	5	5	5	5
14	50	20.7	9.2	5	5	5	5	5
15	44	20.8	10.7	5	4	5	5	5
16	46	19.6	7.2	5	4	5	5	5
17	39	19.6	9.6	5	5	5	5	5
18	48	21.1	8.4	5	5	5	5	5
19	52	20.4	10.4	5	5	5	5	5
20	54.5	24.5	11.9	5	5	5	5	5
21	45.5	22.4	9.6	5	5	5	5	5
22	52	24.9	14.2	5	5	5	5	5
23	57	23.1	11.1	5	5	5	5	5
24	52	24.2	9.6	5	5	5	5	5
25	52.5	24.6	9.9	5	5	5	5	5
26	46	24.4	12	5	4	5	5	5
27	46	25.8	14.1	5	5	5	5	5
28	54	22.5	12.3	5	5	5	5	5
29	56.5	19.9	10.8	5	4	5	5	5

Plus tree ordinal number	Diameter at breast height (cm)	Height (m)	Main stem length (m)	Stem form quality	Crown form quality	Fullness of bole	Twisting of main stem	Health condition
30	50.5	23.7	12.7	5	5	5	5	5
31	43	24.8	14.5	5	5	5	5	5
32	43.5	24.9	13.3	5	5	5	5	5
33	42.5	18.5	6.2	4	5	5	5	5
34	61	26.9	13.4	5	5	5	5	5
35	49.5	24.1	9.7	5	5	5	5	5
36	34.5	21.8	10.1	5	5	5	5	5
37	36.5	25.5	10.1	5	5	5	5	5
38	66	29.5	8.5	5	5	5	5	5
39	49.5	23.9	7.8	5	5	5	5	5
40	46	19.9	8.2	5	5	5	5	5
41	52	21.7	11.2	5	5	5	5	5
42	50	25.7	10.7	5	5	5	5	5
43	57	21.7	6.5	5	5	5	5	5
44	39	21.6	9.8	5	5	5	5	5
45	53	20.6	7.3	5	5	5	5	5
46	46	24.3	9.6	5	5	5	5	5
47	42	18.9	5.1	5	5	5	5	5
48	41	21.9	9.4	5	5	5	5	5
49	36	20.6	9	5	5	5	5	5
50	37	19.8	8.5	5	5	5	5	5
51	54	25	11	5	5	5	5	5
52	34	19	5.5	5	5	5	5	5
53	54	26.7	14.5	5	5	5	5	5
54	50	24.6	12.1	5	5	5	5	5
55	44	22.7	11.6	5	5	5	5	5
56	46	26.8	12.3	5	5	5	5	5
57	53	25.4	14.1	5	5	5	5	5
58	52	23.9	9.3	5	5	5	5	5
59	55	26.5	12.1	5	5	5	5	5
60	52	24.4	12.4	5	5	5	5	5
61	59	24.8	12.3	5	5	5	5	5
62	48.5	24.7	9.5	5	5	5	5	5
63	45	26.3	15.5	5	5	5	5	5
64	54	31.8	15.5	5	5	5	5	5
65	45	23	12.6	5	5	5	5	5
66	43	22.6	11.8	5	5	5	5	5
67	53	24	12.3	4	5	5	5	5
68	50.5	26.1	13.6	5	5	5	5	5
69	55	27.5	14.7	5	5	5	5	5
70	50	24.8	15.2	4	5	5	5	5
71	46.5	23.9	12.8	5	5	5	5	5
72	46	25.7	11.5	5	5	5	5	5
73	50.5	26.7	16.2	5	5	5	5	5
74	48	28	13.5	5	5	5	5	5
75	58	23	9	4	5	5	5	5
76	54	22	8.5	5	4	5	5	5
77	68	24.9	10.9	5	5	5	5	5
78	55	26.5	12.8	5	5	5	5	5
79	54	29.7	14.4	5	5	5	5	5
80	37	23.4	12.2	5	4	5	5	5
81	50.5	25.6	10	5	5	5	5	5
82	93	22.8	10.8	4	5	5	5	5
83	45	24.5	11.9	5	5	5	5	5
84	60	24.5	7.7	4	5	5	5	5
85	51	24.8	10.6	5	5	5	5	5
86	74.5	21.6	8.9	5	5	5	5	5

Morphometric analysis of leaves

Morphometric characteristics of leaves indicate pronounced variability among plus trees. Average leaflet area at the level of population amounted to 41.28 cm², with a minimum of 7.60 cm² and a maximum of 145.73 cm². The mean value of the leaflet length amounted to 98.63 mm, while the average width amounted to 59.25 mm. Leaflet length-to-width ratio was relatively stable (mean value 1.52), which indicates lower variability of this indicator compared to leaflet area or circumference. Leaflet area was the most variable characteristic (CV = 45.39%), while leaflet length-to-width ratio showed the lowest coefficient of variation (CV = 13.24%) (Table 2).

Table 2. *Basic indicators of descriptive statistics of morphometric parameters of the leaves*

Characteristic	Mean value	Minimum	Maximum	Standard deviation	Coefficient of variance
LA (cm^2)	41.28	7.60	145.73	18.38	45.39
LC (cm)	31.56	11.21	76.88	9.51	24.11
LW (mm)	59.25	19.03	156.77	15.89	23.56
LW25 (mm)	47.10	13.52	145.51	14.71	29.71
LW50 (mm)	53.45	16.55	137.79	15.31	28.28
LW75 (mm)	41.59	7.42	124.56	13.82	31.14
LL (mm)	98.63	38.85	185.35	22.18	21.16
LL25 (mm)	73.44	23.90	143.33	17.51	21.06
LL50 (mm)	97.36	7.05	181.36	22.81	20.42
LL75 (mm)	74.54	25.84	138.24	17.48	23.19
LL/LW	1.52	0.69	2.81	0.22	13.24
PL (cm)	2.14	1.02	4.42	0.47	21.18

Abbreviations: LA – leaflet area (cm^2); LC – leaflet circumference (cm); LW – leaflet width at the widest part of the leaflet (mm); LW25- leaflet width at 25% of leaflet length (mm); LW50- leaflet width at 50% of the leaflet length (mm); LW75- leaflet width at 75% of the leaflet length (mm); LL – leaflet length (mm); LL25 – leaflet length at 25% of the leaflet width (mm); LL50 – leaflet length at 50% of leaflet width (mm); LL75- leaflet length at 75% of leaflet width (mm); LL/LW-ratio of leaflet length and width; PL- petiole length (mm).

Table 3. *One-way analysis of variance for measured morphometric characteristics of leaves*

	F	p
LA		
Intercept	14350.91	0.0000
Tree	16.72	0.0000
LC		
Intercept	36344.16	0.0000
Tree	13.45	0.0000
LW		
Intercept	40261.50	0.0000
Tree	14.45	0.0000
LW25		
Intercept	29783.20	0.0000
Tree	10.93	0.0000
LW50		
Intercept	34295.40	0.0000
Tree	13.21	0.0000
LW75		
Intercept	30221.00	0.0000
Tree	18.34	0.0000

	F	p
LL		
Intercept	58325.42	0.0000
Tree	14.15	0.0000
LL25		
Intercept	47814.69	0.0000
Tree	11.33	0.0000
LL50		
Intercept	53357.70	0.0000
Tree	13.61	0.0000
LL75		
Intercept	48913.69	0.0000
Tree	12.15	0.0000
LL/LW		
Intercept	165798.9	0.0000
Tree	27.5	0.0000
PL		
Intercept	26259.69	0.0000
Tree	19.11	0.0000

The results of one-way analysis of variance (ANOVA) showed that there are statistically significant differences among plus trees ($p < 0.01$) for all observed morphometric characteristics of leaves. This confirms a high level of intraspecific variability and indicates the possibility of selection of trees with the favourable morphometric characteristics (Table 3).

Morphometric analysis of the acorn

Mean length of acorn amounted to 26.14 mm (min 20.54 – max 39.78 mm), thickness 15.44 mm (min 6.08 – max 23.84 mm), while mean mass was 3.85 g, with an extremely high range (0.82 – 30.35 g). Coefficient of variation was highest for the acorn mass (CV = 39.74%), while acorn length showed moderate variability (CV = 14.80%), and thickness was somewhat lower (CV = 13.08%) (Table 4).

Table 4. *Basic indicators of descriptive statistics of morphometric parameters of acorns*

Characteristic	Mean value	Minimum	Maximum	Standard deviation	Coefficient of variation
Acorn length (mm)	26.14	20.54	39.78	3.87	14.80
Acorn thickness (mm)	15.44	6.08	23.84	2.02	13.08
Acorn mass (g)	3.85	0.82	30.35	1.53	39.74

Table 5. *One-way analysis of variance for measured morphometric characteristics of acorns*

	F	p
Acorn length		
Intercept	353082.8	0.0000
Tree	41.8	0.0000
Acorn thickness		
Intercept	400243.5	0.0000
Tree	31.6	0.0000
Acorn mass		
Intercept	39909.89	0.0000
Tree	24.90	0.0000

The analysis of variance confirmed the existence of statistically significant differences among trees for all three observed characteristics ($p < 0,01$). These results show that the trees possess a significant level of genetic and morphological diversity, which is the basis for their further use in selection (Table 5).

By combining the results of morphometric analyses of leaves and acorns, a satisfactory level of genetic diversity is observed among the selected plus trees. This diversity enables the selection of individuals with the most favourable combinations of characteristics, while minimizing the risk of genetic closeness and inbreeding in future seed orchard.

Geographic characteristics of plus trees

All plus trees are geographically positioned and recorded with read off coordinates and altitude. The altitude ranged from about 285 m to 647 m of altitude, which indicates a wide ecological amplitude of selected trees. These data represent the basis for the preparation of the plus trees distribution map, which enables precise monitoring and management of genetic resources (Table 6, Figure 1).

In summary, the results show a high level of morphological and genetic variability among plus trees of sessile oak, with clearly identified candidates for a source of high-quality reproductive material. That provides a firm basis for forming a seed orchard with significant potential for conservation and improvement of the species gene pool.

Table 6. *Basic geographical data*

Plus tree ordinal number	Geographical coordinates		Altitude
	X	Y	
1	4919937	7578945	578
2	4919992	7578906	581
3	4920024	7778929	582
4	4920082	7878920	584
5	4920101	7978872	578
6	4920232	8078833	567
7	4920364	8178759	562
8	4920441	8278599	556
9	4920494	8378571	563
10	4920490	8478493	586
11	4920519	7578328	595
12	4920477	7578279	606
13	4920499	7578148	638
14	4920636	7578081	647
15	4920534	7578380	582
16	4921829	7578406	631
17	4921775	7578416	614
18	4921715	7578429	591
19	4921667	7578508	591
20	4921607	7578584	582
21	4921547	7578761	580
22	4921456	7578838	567
23	4921351	7578996	577
24	4921308	7578954	575
25	4921195	7578926	572
26	4921101	7578909	554
27	4921039	7578882	530
28	4921721	7578235	572

Plus tree ordinal number	Geographical coordinates		Altitude
	X	Y	
29	4921621	7578112	556
30	4921396	7578142	592
31	4921268	7578082	592
32	4920935	7578284	587
33	4917005	7580571	521
34	4916905	7580519	499
35	4916826	7580542	502
36	4916800	7580608	493
37	4916759	7580691	473
38	4916766	7580510	515
39	4916735	7580411	509
40	4916679	7580447	519
41	4916640	7580518	497
42	4916678	7580580	476
43	4916569	7580536	492
44	4916537	7580583	477
45	4916481	7580574	470
46	4916485	7580621	472
47	4916435	7580644	471
48	4916365	7580618	444
49	4916371	7580661	456
50	4916 691	7580348	486
51	4916814	7580365	482
52	4916788	7580180	441
53	4918066	7569606	506
54	4918043	7569658	490
55	4918007	7569735	493
56	4917890	7569789	460
57	4917884	7569775	455
58	4917767	7569821	458
59	4917583	7569914	452
60	4917493	7569972	466
61	4917480	7570075	471
62	4917352	7570143	456
63	4917250	7570238	442
64	4917268	7570350	431
65	4917160	7570414	433
66	4917154	7570483	420
67	4917156	7570544	415
68	4917096	7570674	395
69	4917073	7570738	393
70	4917021	7570784	384
71	4916994	7570844	351
72	4916950	7570923	368
73	4916899	7570964	349
74	4916768	7571017	325
75	4916825	7570905	323
76	4916950	7570680	285
77	4921793	7578166	587
78	4921838	7578277	594
79	4922048	7578248	624
80	4922060	7578193	618
81	4922067	7578267	604
82	4922270	7578321	639
83	4922363	7578211	628
84	4922704	7578532	630
85	4922959	7578423	644
86	4923173	7578680	612

4. DISCUSSION

Previous research showed that seed orchards with 30 to 50 unrelated clones keep the degree of genetic variability like the ones in natural populations (Ruņģis et al., 2019; Cortés et al., 2020; Pakull et al., 2021; Sang et al., 2022). In our case 86 plus trees were selected, representing a good starting genetic base for a future seed orchard.

Genetic diversity is manifested at the phenotypic level, in interaction with environmental conditions. It was shown that functional diversity, as well as diversity of various morphological characteristics of trees increases forest productivity and long-term resistance to climatic stressors (Sakschewski et al., 2016; Hisano et al., 2024), and that is one of the long-term goals when establishing seed orchard.

Dobrosavljević et al. (2022) showed that the diameter of sessile oak tree is positively correlated with the number of acorns per m^2. This is a consequence of the increase of crown area which increases with the increase of tree diameter (Bechtold 2003). The same study also established a link between larger tree diameter with larger acorn length and diameter.

The coordinates of selected plus trees confirm their mutual distance, which is significant for the prevention of inbreeding. Sessile oak has a very wide altitudinal range of spreading and it grows on altitudes from 0 to 2200 m (Nicolescu et al., 2025). Considering the topography of the area and the original stands in which the selection of plus trees was carried out, a relatively wide ecological amplitude of the species in the given area is covered. In this way, it is ensured that the genetic and morphological variability of the future seed orchard is increased, because each of the trees is specifically adapted to the conditions of its immediate microenvironment. Consequently, the probability of success of future afforestation, which will derive from the seeds of selected plus trees, increases.

In our research, the morphological parameters of acorns were also examined. The effect of population and maternal effect determine acorn dimensions (Gonzalez-Rodriguez et al., 2011). The largest part of the acorn mass consists of cotyledons (Giertych et al., 2019). Larger acorns are associated with later more robust and higher quality seedlings with greater survival success (Roth et al., 2009; Dobrosavljević et al., 2018), due to greater nutrient supplies. Germination percent was more than double for the group of larger acorns. Large acorns produced seedlings with greater dry weight of roots and lower shoot to root ratios (Devetaković et al., 2019). Also, the research of Sánchez-Montes de Oca et al. (2018) showed that heavier seeds germinate earlier. However, some authors also link the size of acorns with the method of seed dispersal (Perea et al., 2012; Wrobel and Zwolak 2017). Also, the largest acorns are often the most interesting to predators such as wild boars and mice (Gomez 2004).

It is important to note that the quality of seedlings, in accordance with the concept of targeted seedling production, is assessed also based on both the needs and final planting location (Grossnickle MacDonald, 2018), so the acorns of more modest dimensions must not be rejected a priori as future less successful seedlings. In addition to their role in preserving population variability and stability, it should be borne in mind that smaller seedlings are a competitive advantage in certain environmental conditions.

The characteristics of acorns are also important in the context of pathogen attack. Dobrosavljević et al. (2022) reported a significantly negative effect of acorn length on the rate of infection by harmful insects of the genera *Curculio* and *Cydia*, and confirmed a significant positive effect on the germination rate, while acorn diameter did not have a significant influence on the mentioned characteristics. The same study determined that the size of an acorn affects the rate of attack of the pest *Curculio glandium* (Marsham 1802) and the germination rate of damaged and healthy acorns.

Like acorns, sessile oak leaves show great variability in morphological parameters. The differences in length, width, circumference and leaflet area are also reflected in its productivity (Marron Ceulemans 2006). Kissling et al. (1980) indicate narrower base, shallower lobes, less hairiness and shorter petiole of oak leaves in secondary seasonal growth compared to the primary. Variability of morphological parameters of sessile oak leaves can also be the consequence of stressful environmental conditions, so in the conditions of drought and nitrogen deficiency smaller and thicker leaves develop, while in favourable environmental conditions they are larger and thinner (Arab et al., 2020; Arab et al., 2021; Thomas et al., 2024). Larger leaves enable faster plant growth, supplying it with larger quantities of photosynthetic products.

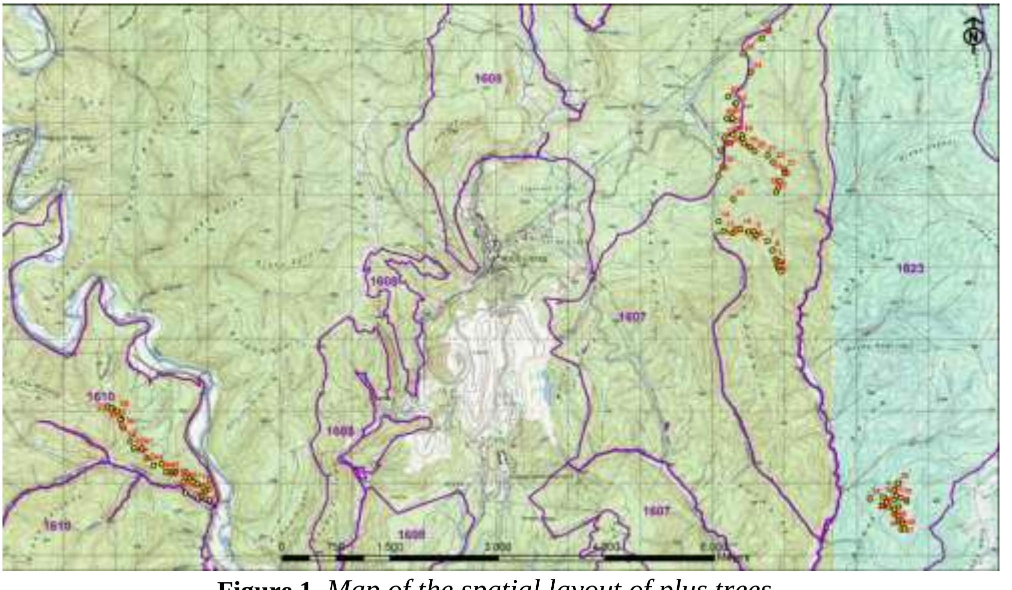

Figure 1. *Map of the spatial layout of plus trees*

5. CONCLUSION

Results of this research show that the selected plus trees of sessile oak exhibit a high degree of morphological and genetic variability, which is of crucial importance for their future application in seed production and programs of conservation of genetic resources. Significant differences in morphological parameters of leaves and acorns indicate the existence of trees with desirable combinations of characteristics that can be used as sources of reproductive material in establishing seed orchard.

Selection material includes trees of different geographical origins and altitude range, which additionally provides a wide adaptive basis for future plantations. The data on morphometric characteristics of acorns show that selected plus trees produce larger acorns, which indicates greater potential for germination and development of more vital seedlings.

This research represents an important step toward establishing a genetically valuable and productive source of sessile oak reproductive material, which will contribute to more efficient restoration and conservation of this economically and ecologically significant species.

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SELECTION OF SESSILE OAK (*Quercus petraea* (Matt.) Liebl.) PLUS TREES FOR SEED ORCHARD ESTABLISHMENT

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Summary

The research represents a part of the program of selection and conservation of genetic resources of sessile oak (*Quercus petraea* (Matt.) Liebl.) in Serbia, with the aim of identifying and selecting plus trees as a basis for establishing a seed orchard. This paper analysed the total of 86 trees of phenotypically highest quality, selected based on the criteria of morphological regularity, physiological vitality, proportionality of the crown, fullness of the bole, and satisfactory seed production.

Samples of leaves and acorns were collected from each tree and detailed morphometric measurements were carried out on them. The leaves were analysed using LAMINA software, while the dimensions and mass of the acorns were measured by precise laboratory instruments. The results showed a high degree of variability in the morphological characteristics of both leaves and acorns. Analysis of variance (ANOVA) confirmed statistically significant differences among trees for all observed characteristics ($p < 0.01$), which indicates pronounced intraspecific genetic and morphological variability.

By combining the results of morphometric analyses of acorns and leaves, it can be concluded that the selected trees represent a genetically valuable basis for the seed orchard establishment. High variability ensures sufficient genetic distance between individuals and reduces the risk of inbreeding, which is crucial for preserving the vitality of future generations. At the same time, the selected trees come from different habitats and altitudes (285-647 m), which expands ecological amplitude and increases the adaptive potential of future reproductive material.

The obtained results have a practical significance in planning and organization of production of high-quality forest reproductive material, as well as in defining the program of conservation of autochthonous genetic resources of sessile oak. Establishing a seed orchard based on plus trees selected in this way represents a key step in the long-term strategy of conservation, adaptation and improvement of populations of this economically and ecologically significant tree species in Serbia.

SELEKCIJA PLUS STABALA HRASTA KITNJAKA (*Quercus petraea* (Matt.) Liebl.) ZA POTREBE OSNIVANJA SEMENSKE PLANTAŽE

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Rezime

Istraživanje predstavlja deo programa selekcije i očuvanja genetičkih resursa hrasta kitnjaka (*Quercus petraea* (Matt.) Liebl.) u Srbiji, sa ciljem identifikacije i odabira plus stabala kao osnove za osnivanje semenske plantaže. U radu su analizirana ukupno 86 fenotipski najkvalitetnija stabala, izdvojena na osnovu kriterijuma morfološke pravilnosti, fiziološke vitalnosti, proporcionalnosti krošnje, punodrvnosti i zadovoljavajuće semenske produkcije.

Sa svakog stabla sakupljeni su uzorci listova i žireva, na kojima su sprovedena detaljna morfometrijska merenja. Listovi su analizirani korišćenjem LAMINA softvera, dok su dimenzije i masa žireva merene preciznim laboratorijskim instrumentima. Rezultati su pokazali visok stepen varijabilnosti morfoloških svojstava i listova i semena. Analiza varijanse (ANOVA) potvrdila je statistički značajne razlike među stablima za sva posmatrana svojstva ($p < 0{,}01$), što ukazuje na izraženu intraspecifičnu genetičku i morfološku varijabilnost.

Kombinacijom rezultata morfometrijskih analiza žira i lista može se zaključiti da odabrana stabla predstavljaju genetički vrednu osnovu za formiranje semenske plantaže. Velika varijabilnost obezbeđuje dovoljnu genetičku distancu između jedinki i smanjuje rizik od srodničkog ukrštanja, što je ključno za očuvanje vitalnosti budućih generacija. Istovremeno, izdvojena stabla potiču sa različitih staništa i nadmorskih visina (285-647 m), što proširuje ekološku amplitudu i povećava adaptivni potencijal budućeg reproduktivnog materijala.

Dobijeni rezultati imaju praktičan značaj u planiranju i organizaciji proizvodnje šumskog reproduktivnog materijala visokog kvaliteta, kao i u definisanju programa konzervacije autohtonih genetičkih resursa hrasta kitnjaka. Uspostavljanje semenske plantaže na osnovu ovako selekcionisanih plus stabala predstavlja ključni korak u dugoročnoj strategiji očuvanja, adaptacije i unapređenja populacija ove ekonomski i ekološki značajne vrste drveća u Srbiji.