UDK 630*164
https://doi.org/10.31298/sl.147.11-12.5

Prethodno priopćenje – Preliminary communication
Šumarski list, 11–12 (2023): 547–554

STOCKTYPE IMPACT ON SURVIVAL AND GROWTH OF ONE-YEAR OLD *QUERCUS PUBESCENS* SEEDLINGS ON THE EDGE OF PANONNIAN BASIN

UTJECAJ TEHNOLOGIJE PROIZVODNJE NA PREŽIVLJAVANJE I RAST JEDNOGODIŠNJIH SADNICA *Quercus pubescens* NA RUBU PANONSKOG BAZENA

Jovana DEVETAKOVIĆ[1], Associate Professor (vanredni professor) Milutin ĐILAS[2], Junior Researcher (istraživač pripravnik) Ivona KERKEZ JANKOVIĆ[1], Research Assistant (istraživač saradnik)

SUMMARY

Querqus pubescens has relatively wide distribution in Europe, but dominated forests are quite common in South Europe, while they are confined to warm microclimatic conditions in central Europe. On the edge of the Panonnian basin *Q. pubescens* is mainly found on the edge of its native range, in isolated populations which have an important role in examining the adaptive potential, especially considering that the forest-steppe and sub-mediterranean climate is predicted to be the dominant climate in some regions of Central Europe in future. There are very limit knowledge about *Q. pubescens* forest establishment and restoration in continental climate today. This study provides information about stocktype effect on seedlings success after outplanting in very competitive conditions. Although bareroot seedlings were larger in the nursery, container seedlings had better survival and growth on the field. Generally, low survival rate for both stocktypes (mean survival 47.60 %; container seedlings 55.41%; bareroot seedlings 41.41%) can be assessed as consequence of uncompetitive seedlings and lack of vegetation control.

KEY WORDS: stocktype, survival, growth, lack of vegetation control, restoration

INTRODUCTION
UVOD

Oak forests are represented for the most part of Balkan Peninsula and Southeast Europe, but their condition and perspectives are related to composition of species and ecological conditions which vary from site to site. According to last forest inventory in Serbia, about 30% of forest area belongs to oaks forest, while more than half of them are coppice forest (Banković *et al.*, 2009). One of native oaks in Serbia is Pubescent or Downy oak (*Quercus pubescens* Wild.) which is frequent member of polydominant oak forests, but with significant lower distribution then *Q. cerris*, *Q. petraea*, *Q. frainetto* and *Q. robur* (Cvjetićanin *et al.*, 2016). Since *Q. pubescens* is mainly distributed in central and southern Europe and it is one of the most important forest tree species in south-central and south-eastern Europe and Anatolia (Bordács *et al.*, 2019), so majority of data for *Q. pubescens* seedlings field performance are available for Mediterranian region. *Q. pubescens* dominated forests are quite common in South Europe, while they are confined to warm microclimatic conditions in central Europe

[1] University of Belgrade - Faculty of Forestry, Kneza Višeslava 1, Belgrade, Serbia
[2] Institute of Lowland Forestry and Environment, Antona Čehova 13d, Novi Sad, Serbia

(Pasta *et al.*, 2016). On the edge of the Panonnian basin *Q. pubescens* is mainly found on the edge of its native range and in isolated populations (Caudullo *et al.*, 2017). These populations have an important role in examining the adaptive potential and field performance of the seedlings, especially considering that the forest-steppe and sub-mediterranean climate is predicted to be the dominant climate in some regions of Central Europe (Bordács *et al.*, 2019). Projections of the regional climate model for south-east Europe generally predict an increasing of temperature and a decreasing of precipitation (Ivetić, Devetaković, 2016), which indicate possibility to promote Q.*pubescens* as a potential species for oak forest restoration on the continental areas of Balkan and increasing their participation in forests. As heliophilous and thermophilous species tolerant on low precipitation level (<400 mm in vegetation period), summer drought and poor and eroded soils (Bordács *et al.*, 2019) adaptive potential of pubescent oak, but as well as seedlings quality and management might have an increasing role in present and potential future distributional range. Seedlings attributes do not the only one predictor of future success, but it is important one, since artificial regeneration is interaction complex between species, planting and site conditions (South, 2000). Seedlings stocktype could be marked as one of factors which predict future success, and numerous trials reported advantages of container seedlings (Grossnickle, El-Kassaby, 2016). Beaside that, morphological attributes can be predictor of seedlings performance at the field (Tsakaldimi *et al.*, 2012). There are studies which promote better morphological attributes as predictor for better survival (Villar-Salvador *et al.*, 2004; Tsakaldimi *et al.*, 2005; Villar-Salvador, 2012) and growth (Villar-Salvador *et al.*, 2004; Ivetić *et al.*, 2016) on the field for oak seedlings. Preplanting operations have great role in survival of seedlings, planting date and soil preparation showed significant influence on survival and growth of *Q.ilex* seedlings in Mediteranian conditions (Palacios *et al.*, 2009). High intensity soil preparation treatments can help survival of lower quality seedlings (South *et al.*, 2001). Pre- and post-planting weed control is desirable and using different methods improve oak seedlings establishment (Ezell, Hodges, 2002; Löf *et al.*, 2006; Ezell *et al.*, 2007), often better than using tree shelters or natural shade (Mc Creary *et al.*, 2011). Study with two Mediterranean oaks in combination with neighbored species showed high competition sensibility of *Q.pubescens* seedlings and better results in control where it was competitive to natural weed vegetation (Prévosto *et al.*, 2015). Interactions between plants on the field are complex and complicated and in some cases negative effects of competition are lower than benefits. There are several studies which reported positive effect of shrubs on oak seedlings survival and growth in Mediteranian conditions (Gómez-Aparicio *et al.*, 2004; Padilla, Pugnaire, 2006; Rousset, Lepart, 1999).

Natural regeneration of oak forests is induced by seed production, seed viability, seed survival, seed dispersal, seedling establishment and sampling growth and survival (Pulido, Díaz, 2005). Reasons for poor oak regeneration could be caused by many factors such as limiting light conditions when oaks are out-competed by more shade-tolerant species or in the conditions after clearcut (light are not limited) when faster-growing species often out-compete oak (Iverson,2008). Natural regeneration of oaks were promoted as primarily method, but there are increasingly more situations in which high potential for oak regeneration failure dictates the use of artificial regeneration including direct seeding and planting seedlings (Dey *et al.*, 2008). If artificial regeneration observed as planting, many problems can be exceed, but work method need be different and intent on seedlings performance and solving on pre- and post-planting conditions.

However, there are very limit knowledge about *Q.pubescens* forest restoration and regeneration in the continental areas, so this study was provided with aim to obtained recommendation about seedlings stocktype for planting in continental Balkan areas for purpose of pubescent oak forests restoration.

MATERIAL AND METHOD
MATERIJALI I METODE

Seed origin – *Porijeklo sjemena*

Acorns were collected in the Natural Monument "Košutnjak Forest" (44.772730, 20.432714), located in Belgrade (Serbia). It is an isolated forests complex, surrounded by an urban area. In a floristically diverse forest four native oak species are present: *Q. cerris*, *Q. petraea, Q. frainetto* and *Q. robur*, as well as *Q.rubra* as non-native (Šijačić-Nikolić *et al.*, 2021). Given the high rate of hybridization of this species, selection of morphologically typical individuals was needed. In total 88 trees were selected, but acorns were collected from 20 selected maternal trees. Except morphological traits of trees, spatial area was also taken into consideration with preferring long distance trees or tree groups (Figure 1).

Nursery trial – *Rasadnički ogled*

Collected acorns were shortly storage into basement (no more than two weeks) before nursery sowing. Nursery trial was established in the last week of October 2019 in nursery near originate population (44.782498, 20.425315). Sowing was performed in seedbeds and containers. In seedbeds density was 50 seeds m^{-1} and distance between rows 20 cm. In the same time, containers (Bosnaplast 18) were filled

Figure 1. Spatial distribution of 20 selected maternal trees
Slika 1. Prostorni raspored 20 odabranih matičnih stabala

with peat and forest soil mixture (1:2) and one acorn per cell was placed. Germination was noticed on the start of April 2020 in seedbeds and two weeks later into containers and it was finished on the half May. Germination percent was near 50 % in both stocktypes. During growing period seedlings were ordinarily irrigated with several hand weeding. Fertilization were performed uniformly for both seedlings types during 6 weeks from middle June to middle July (Fitogal S®- Galenika, according producer prospects).

Field trial – *Terenski pokus*

Establishment site (44.777569, 20.429238) previous were planted mixed forest of pines (*P.nigra* and *P. sylvestris*) and deciduous species (*Fraxinus excelsior, Tilia argentea, Prunus avium, Quercus cerris, Quercus petraea, Castanea sativa*), marked as low valuable forest from several aspects. Situation on the field indicated need for sanitary logging and restoration in the aim to promote natural vegetation. Soil conditions, elevation, exposition and climatic characteristics indicated possibilities of oak forest establishment with giving priority for *Q.pubescens*. Site preparation was conducted after a clearcut. It included logging and removal of trees and shrubs with mechanical grinding of remains. Planting was performed in the first half of December 2020. Planting holes (30 x 30 cm) were prepared by mechanical driller several days before. Bareroot seedlings were transported in plastic bags from nursery, while containers seedlings were transported in containers. Planting sites were squarely randomized on the distance 3 m and random arrangement of different stocktype seedlings was performed during planting. Total of 408 seedlings were planted and marked accordingly to stocktype. Mechanical weed control between seedlings was provided only once – in the last week of May.

Table 1. Temperature and precipitation per months for year 2021 and their differences from reference period 1990-2020. (Source: https://www.hidmet.gov.rs/)
Tablica 1. Temperatura i oborina po mjesecima za 2021. godinu i njihove razlike u odnosu na referentno razdoblje 1990.-2020.

Month *Mjesec*	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year Average *Prosječno godišnje*
Temperature *Temperatura* [°C]	3.8	6.5	6.7	10.1	17.0	23.7	25.9	23.4	19.3	11.5	8.6	3.7	13.4
Deviation *Odstupanje* (reference value / *referentna vrijednost*)	↑1.9 (1.9)	↑2.7 (3.8)	↓1.6 (8.3)	↓3.5 (13.6)	↓1.2 (18.2)	↑1.8 (21.9)	↑2.1 (23.8)	↓0.4 (23.8)	↑0.8 (18.5)	↓1.8 (13.3)	↓0.2 (8.1)	↓0.7 (3.0)	↑0.2 (13.2)
Precipitation *Padavine* [mm]	60.6	34.0	57.6	51.9	85.8	22.9	93.6	39.6	18.8	71.0	132.8	147.2	815,8
Deviation *Odstupanje* (reference value / *referentna vrijednost*)	↑12.7 (47.9)	↓9.5 (43.5)	↑8.9 (48.7)	↑0.4 (51.5)	↑13.5 (72.3)	↓72.7 (95.6)	↑27.1 (66.5)	↓15.5 (55.1)	↓39.8 (58.6)	↑16.2 (54.8)	↑83.2 (49.6)	↑92.4 (54.8)	↑116.9 (698.9)

Meteorological data for observed year were obtained from local meteorological station (44.772013, 20.424490) and presented in Table 1, while deviation from normal.

Seedlings measurement – *Mjerenja sadnica*

At nursery stage, total of 232 seedlings (106 bareroot and 126 container seedlings) were carefully lifted at the end of growing season and stored in the fridge (5 °C). During next two weeks, seedlings were measured for: shoot height (h), root collar diameter (d) and dry mass of shoot (m_s) and root (m_r) after drying during 48 h at temperature 68 ± 2°C (Ivetić, 2013). Obtained values were used for calculation saturdeness qoeficient (SQ - Roller, 1997), shoot to root ratio (m_s: m_r) and quality index (QI - Dickson *et al.*, 1960). Average values according standard deviation values (SD) were calculated for each observed parameter with separation of minimal and maximal values.

In field trial, shoot height (H) and diameter above ground level (D) were measured firstly in February 2021 (eight weeks after planting), and then in February 2022 (H1 and D1). Relative to the initial values of H and D an increment (H%, respectively D%) was calculated as:

$$H\% = (\frac{H2}{H1} \times 100) - 100$$

$$D\% = (\frac{D2}{D1} \times 100) - 100$$

Number of viable seedlings was estimated in June 2020, but survival (S) was estimated as difference between planting seedlings and viable seedlings after first growing season on the field. Average values according standard deviation values (SD) were calculated for each observed parameter with separation of minimal and maximal values for H1 and D1, respectively H2 and D2.

All measurements are analyzed in the software Statistica 7.0.

RESULTS
REZULTATI

Seedlings – *Sadnice*

Most of observed parameters are stronger at bareroot seedlings (h, SQ, m_s, m_r, m_s:m_r, QI), except root collar diameter (d) which is slightly stronger at container seedlings (3.04 in comparision to 3.01 at bareroot seedlings) (Table 2).

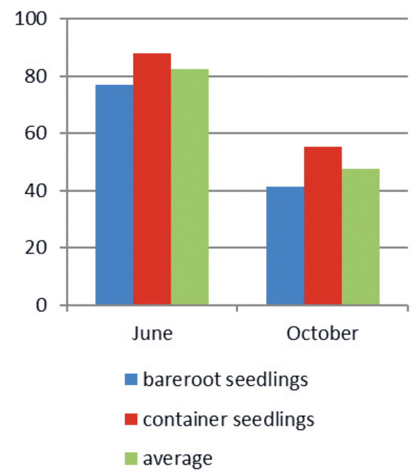

Figure 2. Survival of different stocktype seedlings during first growing season on the field

Slika 2. Preživljavanje različitih tipova sadnica tijekom prve vegetacijske sezone na terenu

Table 2. Morphological attributes of seedlings in the nursery by stocktype

Tablica 2. Morfološka svojstva sadnica u rasadniku prema tehnologiji proizvodnje

	BAREROOT SEEDLINGS *SADNICE GOLOG KORIJENA*		CONTAINER SEEDLINGS *KONTEJNERSKE SADNICE*		AVERAGE *PROSJEČNA VRIJEDNOST*	
	mean (SD)	min-max	mean (SD)	min-max	mean (SD)	min-max
h	20.25 (8.27)	6.90–44.80	10.02 (2.49)	4.30–15.90	14.69 (7.78)	4.30–44.80
d	3.01 (1.11)	1.20–6.00	3.04 (0.90)	1.00–5.50	3.03 (1.00)	1.00–6.00
SQ	6.89 (1.91)	3.42–12.00	3.53 (1.21)	1.19–7.90	5.07 (2.29)	1.19–12.00
m_s	1.76 (1.43)	0.20–6.70	0.45 (0.23)	0.06–1.07	1.05 (1.18)	0.06–6.70
m_r	2.20 (1.57)	0.11–7.30	0.82 (0.37)	0.13–1.93	1.45 (1.29)	0.11–7.30
m_s:m_r	0.85 (0.41)	0.28–3.36	0.59 (0.24)	0.08–1.41	0.70 (0.35)	0.08–3.36
QI	0.55 (0.41)	0.03–1.98	0.34 (0.18)	0.02–0.94	0.44 (0.32)	0.02–1.98

Table 3. Height and diameter after planting and after first growing period

Tablica 3. Visina i promjer nakon sadnje i nakon prvog razdoblja rasta

	BAREROOT SEEDLINGS *SADNICE GOLOG KORIJENA*		CONTAINER SEEDLINGS *KONTEJNERSKE SADNICE*		AVERAGE *PROSJEČNA VRIJEDNOST*	
	mean (SD)	min-max	mean (SD)	min-max	mean (SD)	min-max
H1	15.2 (5.59)	5.1–33.7	9.9 (2.85)	3.2–18.4	12.5 (5.1)	3.2–33.7
D1	2.9 (0.77)	1.4–4.5	2.4 (0.61)	1.5–3.9	2.75 (0.7)	1.4–4.5
H2	19.1 (7.54)	6.5–43.2	13.3 (4.88)	5.5–38.0	15.6 (7.0)	5.5–43.2
D2	4.0 (1.09)	2.2–8.5	3.4 (1.05)	1.6–6.8	3.70 (1.17)	1.6–8.5

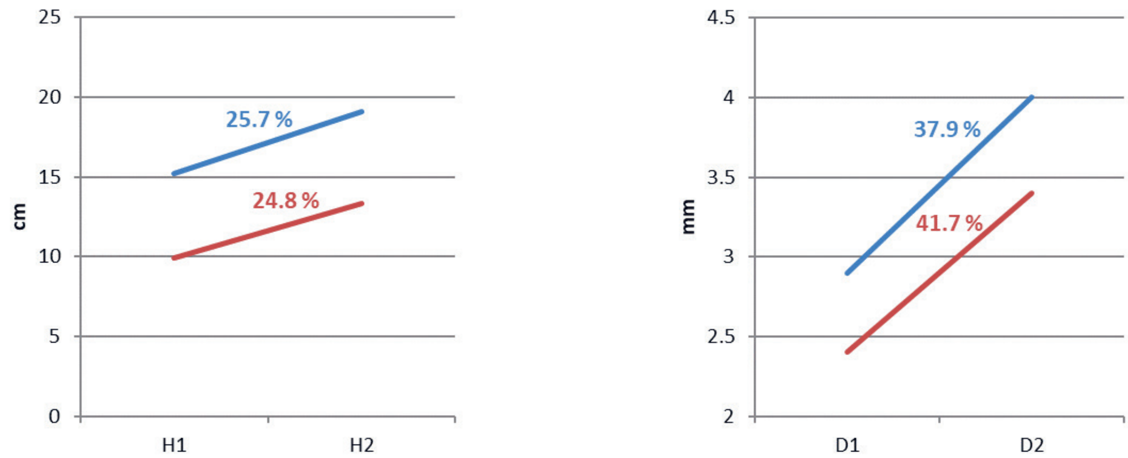

Figure 3. Height (left) and diameter (right) increment of bareroot (blue) and container (red) seedlings during the first growing season after planting on the field

Slika 3. Visinski (lijevo) i debljisnki (desno) prirast sadnica golog korena (plavo) i kontejnerskih sadnica (crveno) tijekom prve vegetacijske sezone nakon sadnje na terenu

Survival and growth – *Preživljavanje i rast*

Six months after planting 88.07% container seedlings were viable, while 77.10% bareroot seedlings were viable. The container seedlings advantage was maintained after first growing season at the field (55.41% relatively to 41.41% for bareroot seedlings), but it was drastically lower with average value 47.60% for total (Figure 2).

After planting H1 and D1 were lower for container seedlings then bareroot seedlings and bareroot seedlings keep advantages after first growing period on the field (Table 3). Diameter growth increment was stronger than height growth increment for both seedlings types (Figure 3). Larger bareroot seedlings had stronger height growth, while container seedlings had stronger diameter growth.

DISSCUSSION
RASPRAVA

Seedlings morphological attributes – *Morfološka svojstva sadnica*

There are evident domination of h average value for bareroot seedlings which is in accordance with previously reported study for *Q.rubra* (Woolerey, Jacobs, 2011). Seedlings from this research were taller than *Q.pubescens* seedlings from Wellesten and Cianfaglione, (2014), reported for seedlings from different European provenances and larger than bareroot seedlings reported by Šušić *et al.*,(2019). Bareroot seedlings from this study were comparable to other oak seedlings from the same or neighbor nurseries but with evident lower d in the same age in comparison to *Q.cerris* (Šušić *et al.*, 2019), *Q.rubra* (Popović *et al.*, 2015; Šušić *et al.*, 2016), *Q.robur* (Popović *et al.*, 2020) and *Q. petraea* (Ivetić *et al.*, 2017) seedlings, while only *Q. frainetto* seedlings were weaker according both attributes (Šušić *et al.*, 2019). *Q.robur* (Popović *et al.*, 2014; Roth *et al.*, 2011; Orešković *et al.*, 2006) and *Q.petraea* (Orešković *et al.*, 2006) seedlings growth in same type of containers were larger, except *Q.robur* seedlings from the same nursery and container type few years ago (Devetaković *et al.*, 2019).

Bareroot seedlings had higher SQ in comparison to container seedlings which is expected if take into consideration seedlings height which average value is double higher. Similar SQ values were noticed for one-year old deciduous bareroot seedlings in Serbian nurseries (Stjepanović, Ivetić, 2013; Ivetić *et al.*, 2013; Popović *et al.*, 2015), but SQ values for container seedlings were lower than values reported by Devetaković *et al.*, (2019), for *Q.robur* container seedlings from same container type.

Dry seedlings mass were more than double at bareroot seedlings, but their relation (m_s: m_r) were similar and can be marked as positive because it suggest better root development in comparison to shoot development. Some higher values of root to shoot ration were recorded for two-year old *Q.pubescens* seedlings in bigger containers and in different water regimes (Fotelli *et al.*, 2000). Dry root mass cannot clearly describe root quality (largest part of mass belong to larger roots), but on the other hand if take into consideration limiting space for root growth into container it can be expected that more fibrosis roots came from containers because central root have barrier to growth deeper. The study conducted on *Q.rubra* seedlings prove better root architecture and root fibrosity at container seedlings than bareroot seedlings (Wilson *et al.*, 2007).

Field success – *Uspjeh sadnica na terenu*

Average survival rate can be considered as unsatisfactory and below average range of deciduous seedlings survival on this area (Ivetić, 2015). Reason for low level of seedlings survival cannot be consider simply. The first year after field planting characterized by low precipitation level and higher average monthly temperature during main part of growing period in comparison to normal (June-September), so summer‘s drought was present to some degree regardless to observed local provenance. There is study which provides information about *Q.pubescens* seedlings sensitivity on drought regardless of the provenance (Wellstein, Cianfaglione, 2014), which confirms term that juvenile individuals might be especially sensitive to climatic extremes in contrast to older trees (Kreyling *et al.*, 2012). Weeding control provides less competitive conditions for seedlings and more water and light, but in this study it was not conducted. In Mediteranian conditions noticed low influence of shrub cover on *Q.pubescens* seedlings survival, while grass cover had strongly negative effect (Prévosto *et al.*, 2015). On the other hand, same study report high influence of competitive vegetation on seedlings height growth. One year old *Q.pubescens* seedlings with stronger H and D and mulching protected after planting in Mediteranian post fire shrub land survived more than 90% two-years after planting and growth was stronger in diameter than in height (Larchevêque *et al.*, 2008), but in lower rate than in this study. Seedlings morphological attributes at planting time don`t necessarily correlate positively with field performance of hardwood seedlings (Jacobs, 2005), and it was confirmed in this study. Container seedlings survived better and showed similar growth intensity although morphological attributes were mostly weaker than bareroot seedlings which can be correlated with stocktype effect on field performance (Grossnickle, El-Kassaby, 2016). Large seedlings usually have larger competitive capacity and study on *Q.rubra* seedlings confirmed diameter influence (Morrissey *et al.*, 2010), but in our study initial diameter were similar for both stocktypes. Numerous reports emphasize importance of weeding control (Ezell *et al.*, 2002; Ezell *et al.*, 2007; Dey *et al.*, 2008) and more competitive seedlings (Wilson *et al.*, 2007: Morrissey *et al.*, 2010) for successful oak stands regeneration.

CONSLUSIONS
ZAKLJUČCI

Seedlings morphological attributes at nursery stage did not show main influence on field success. Seedling stocktype was identified as principal predictor for survival and growth. Low survival level can be marked as a consequence of interaction between seedlings and environmental factors, including absence of weeding control and summer drought. There is a need for *Q. pubesens* seedlings improvement in nursery in order to be more competitive after field planting. Also, this study implicates earlier assertions for necessary weeding control in oak stands restoration and artificial regeneration in the aim success work.

ACKNOWLEDGEMENTS

The paper was supported by the project “Identification and monitoring of the gene pool of rare, vulnerable and endangered plant species in the area of the Košutnjak Forest Natural Monument." financed by Secretariat for Environmental Protection of Belgrade (2019-2021), also as supported by the Ministry of Education, Science and Technological Development of Republic of Serbia according the Agreement with registration number: 451-03-47/2023-01/200169.

REFERENCES
LITERATURA

- Banković, S., M. Medarević, D. Pantić, N. Petrović, B. Šljukić, S. Obradović, 2009: The growing stock of the Republic of Serbia: State and problems, *Glasnik Šumarskog fakulteta*, 100, 7-29.
- Bordács, S., P. Zhelev, B. Schirone, 2019: EUFORGEN Technical Guidelines for genetic conservation and use of pubescent oak (*Quercus pubescens*), European Forest Genetic Resources Programme (EUFORGEN), European Forest Institute, 6 pages.
- Caudullo, G., E. Welk, J. San-Miguel-Ayanz, 2017: Chorological maps for the main European woody species, Data in Brief 12, 662-666.
- Cvjetićanin, R., J. Brujić, M. Perović, V. Stupar, 2016: Dendrologija (Dendrology). University of Belgrade – Faculty of Forestry, p. 557 (on Serbian).
- Dey, D. C., D. Jacobs, K. McNabb, G. Miller, V. Baldwin, G. Foster, 2008: Artificial regeneration of major oak (*Quercus*) species in the eastern United States—a review of the literature, *Forest Science*, 54(1), 77-106.
- Devetaković, J. R., M. Nonić, B. Prokić, M. Šijačić-Nikolić, V. Popović, 2019: Acorn size influence on the quality of pedunculate oak (*Quercus robur* L.) one-year old seedlings, *Reforesta*, 8, 17-24.
- Dickson, A., A.L. Leaf, J. F. Hosner, 1960: Quality appraisal of white spruce and white pine seedlings tock in nurseries, *ForestryChronicle*, 36, 10-13.
- Ezell, A. W., J. F. Yeiser, L. R. Nelson, 2007: Survival of planted oak seedlings is improved by herbaceous weed control, *Weed Technology*, 21(1), 175-178.
- Ezell, A. W., J. D. Hodges, 2002: Herbaceous weed control improves survival of planted Shumard oak seedlings. In: Gen. Tech. Rep. SRS–48, Asheville, NC: US Department of Agriculture, Forest Service, Southern Research Station. pp. 273-275.
- Fotelli, M. N., K. M. Radoglou, H. I. Constantinidou, 2000: Water stress responses of seedlings of four Mediterranean oak species, *Tree physiology*, 20(16), 1065-1075.
- Grossnickle, S. C., Y. A. El-Kassaby, 2016: Bareroot versus container stocktypes: a performance comparison, *New Forests*, 47(1), 1-51.
- Gómez-Aparicio, L., R. Zamora, J. M. Gómez, J. A. Hódar, J. Castro, E. Baraza 2004: Applying plant facilitation to forest restoration: a meta-analysis of the use of shrubs as nurse plants, *Ecological applications*, 14(4), 1128-1138.
- Iverson, L. R., T. F. Hutchinson, A. M. Prasad, M. P. Peters, 2008: Thinning, fire, and oak regeneration across a heterogeneous

landscape in the eastern US: 7-year results, *Forest ecology and management*, 255(7), 3035-3050.

- Ivetić, V., 2013: Praktikum iz Semenarstva, rasadničarstva i pošumljavanja. Univerzitet u Beogradu – Šumarski fakultet, p. 213 (on Serbian).
- Ivetić, V., 2015: Reforestation in Serbia: success or failure?, In International Conference: Reforestation Challenges, Belgrade, Serbia, 3-6 June 2015, Proceedings (pp. 1-12). REFORESTA.
- Ivetić, V., Z. Davorija, D. Vilotić, 2013: Relationship between morphological and physiological attributes of hop hornbeam seedlings, *Glasnik Šumarskog fakulteta*, 108, 39-50.
- Ivetić, V., J. Devetaković, 2016: Reforestation challenges in Southeast Europe facing climate change, *Reforesta,* 1, 178-220.
- Ivetić, V., J. Devetaković, Z. Maksimović 2016: Initial Height and Diameter Are Equally Related to Survival and Growth of Hardwood Seedlings in First Year After Field Planting, *Reforesta*, 2, 6-21.
- Ivetić, V., Z. Maksimović, I. Kerkez, J. Devetaković, 2017: Seedling Quality in Serbia – Results from a Three-Year Survey, *Reforesta*, 4, 27-53.
- Jacobs, D. F., K. F. Salifu, J. R. Seifert, 2005: Relative contribution of initial root and shoot morphology in predicting field performance of hardwood seedlings, *New Forests*, 30(2), 235-251.
- Kreyling, J., T. Bittner, A. Jacschkc, A. Jcntsch, M. J. Steinbaucr, D. Thiel, C. Bcicrkuhnlcin, 2011: Assisted colonization: a question of focal units and recipient localities, *Restoration Ecol*, 19, 433-440.
- Larchevêque, M., N. Montès, V. Baldy, C. Ballini, 2008: Can compost improve *Quercus pubescens* Willd establishment in a Mediterranean post-fire shrubland?, *Bioresource Technology*, 99(9), 3754-3764.
- Löf, M., D. Rydberg, A. Bolte, 2006: Mounding site preparation for forest restoration: Survival and short term growth response in *Quercus robur* L. seedlings, *Forest Ecology and Management*, 232(1-3), 19-25.
- McCreary, D., W. Tietje, J. Davy, R. Larsen, M. Doran, D. Flavell, S. Garcia, 2011: Tree shelters and weed control enhance growth and survival of natural blue oak seedlings, *California Agriculture*, 65(4), 192-196.
- Morrissey, R. C., D. F. Jacobs, A. S. Davis, R. A. Rathfon, 2010: Survival and competitiveness of *Quercus rubra* regeneration associated with planting stocktype and harvest opening intensity, *New Forests*, 40(3), 273-287.
- Orešković, Ž., A. Dokuš, M. Harapin, T. Jakovljević, R. Maradin, 2006: Growing of seedlings common oak (*Quercus robur* L.) and sessile-flowered oak (*Quercus petraea* (Matt.) Liebl.) in different types of containers, *Radovi*, 9, 75-86.
- Padilla, F. M., F. I. Pugnaire, 2006: The role of nurse plants in the restoration of degraded environments, *Frontiers in Ecology and the Environment*, 4(4), 196-202.
- Prévosto, B., J. Gavinet, Y. Monnier, A. Corbani, C. Fernandez, 2015: Influence of neighbouring woody treatments on Mediterranean oak development in an experimental plantation: better form but weaker growth, *Forest Ecology and Management*, 362, 89-98.
- Palacios, G., R. M. N. Cerrillo, A. del Campo, M. Toral, 2009: Site preparation, stock quality and planting date effect on early establishment of Holm oak (*Quercus ilex* L.) seedlings, *Ecological engineering*, 35(1), 38-46.
- Pasta, S., D. de Rigo, G. Caudullo, 2016: *Quercus pubescens* in Europe: distribution, habitat, usage and threats, In: San-Miguel Ayanz J, de Rigo D, Caudullo G, Houston Durrant T, Mauri A (Eds.), European Atlas of Forest Tree Species. Publ. Off. EU, Luxembourg, pp. 156-157.
- Popović, V., A. Lučić, Lj. Rakonjac, 2014: Effect of container type on growth and development of Pedunculate oak (*Quercus robur* L.) seedlings in the nursery, *Sustainable Forestry: Collection*, (69-70), 33-39.
- Popović, V., A. Lučić, Lj. Rakonjac, T. Ćirković-Mitrović, Lj. Brašanac-Bosanac, 2015: Influence of acorn size on morphological characteristics of one-year-old northern red oak (*Quercus rubra* L.) seedlings, *Archives of Biological Sciences*, 67(4), 1357-1360.
- Popović, V., A. Lučić, Lj. Rakonjac, J. I. Kerkez, 2020: Variability of morphometric characteristics of pedunculate oak (*Quercus robur* L.) acorn and one-year seedlings, *Šumarstvo*, 1-2, 1-11.
- Prévosto, B., J. Gavinet, Y. Monnier, A. Corbani, C. Fernandez, 2016:. Influence of neighbouring woody treatments on Mediterranean oak development in an experimental plantation: better form but weaker growth, *Forest Ecology and Management*, 362, 89-98.
- Pulido, F. J., M. Díaz, 2005: Regeneration of a Mediterranean oak: A whole-cycle approach, *Ecoscience,* 12 (1), 92-102.
- Roller, K. J. 1977: Suggested minimum standards for containerised seedlings in Nova Scotia. Department of Fisheries and Environment Canada, Canadian Forestry Service, Information Report MX 69: 1-18
- Roth, V., S. Dekanić, T. Dubravac, 2011: Effect of acorn size on morphological development of one-year-old seedlings of pedunculate oak (*Quercus robur* L.) in differing light conditions, *Šumarski list*, 135(13), 159-167.
- Rousset, O., J. Lepart, 1999: Shrub facilitation of *Quercus humilis* regeneration in succession on calcareous grasslands, *Journal of vegetation science*, 10(4), 493-502.
- South, D. B. 2000: Challenges and predictions in artificial regeneration. In: Advances and Challenges in Forest Regeneration, Robin Rose & Diane L. Haase (eds.), June 1–2, 2000, Embassy Suites, Tigard, Oregon, 5-11p.
- South, D. B., R. W. Rose, K. L. McNabb, 2001: Nursery and site preparation interaction research in the United States, *New Forests* 22, 43-58.
- Stjepanović, S., V. Ivetić, 2013: Morphological indicators of the quality of one-year-old bare-root seedlings of wild cherry (*Prunus avium* L.), *Glasnik Šumarskog fakulteta*, (107), 205-215.
- Tsakaldimi, M., P. Ganatsas, D. F. Jacobs, 2012: Prediction of planted seedling survival of five Mediterranean species based on initial seedling morphology, *New Forests*, 44, 327-339.
- Tsakaldimi, M., T. Zagas,T. Tsitsoni, P. Ganatsas, 2005: Root morphology, stem growth and field performance of seedlings of two Mediterranean evergreen oak species raised in different container types, *Plant Soil,* 278: 85-93..
- Villar-Salvador, P., R. Planelles, E. Enríquez, J. Peñuelas-Rubira, 2004: Nursery cultivation regimes, plant functional attributes, and field performance relationships in the Mediterranean oak *Quercus ilex* L, *Forest Ecol Manag* 196: 257-266.

- Villar-Salvador, P., J. Puértolas, B. Cuesta, J. L. Peñuelas, M. Uscola, N. Heredia-Guerrero, J. M.Rey Benayas, 2012: Increase in size and nitrogen concentration enhances seedling survival in Mediterranean plantations. Insights from an ecophysiological conceptual model of plant survival, *New Forests*, 43, 755-770.
- Wellstein, C., K. Cianfaglione, 2014: Impact of extreme drought and warming on survival and growth characteristics of different provenences of juvenile *Quercus pubescens* Willd, *Folia Geobotanica*, 49(1), 31-47.
- Wilson, E. R., K. C. Vitols, A. Park, 2007: Root characteristics and growth potential of container and bare-root seedlings of red oak (*Quercus rubra* L.) in Ontario, Canada, *New Forests*, 34(2), 163-176.
- Woolery, P. O., D. F. Jacobs, 2011: Photosynthetic assimilation and carbohydrate allocation of *Quercus rubra* seedlings in response to simulated herbivory, *Annals of Forest Science*, 68(3), 617-624.
- Šijačić-Nikolić M., D. Vilotić, V. Ivetić, J. Aleksić, J. Milovanović, M. Nonić, J. Devetaković, D. Jokanović, M. Perović, V. Popović, A. Lučić, I. Kerkez-Janković, V. Jankov, 2021: Identifikacija i monitoring genofonda retkih, ranjivih i ugroženih vrsta biljaka SP „Šuma Košutnjak" – studija. Univerzitet u Beogradu - Šumarski fakultet, Sekretarijat za zaštitu životne sredine grada Beograda, Beograd. (on Serbian)
- Šušić, N., M. Bobinac, M. Šijačić-Nikolić, A. Bauer-Živković, J. Urošević, I. Kerkez Janković, 2019: Growth characteristics of one-year-old seedlings of three autochthonous oak species in suboptimal growing conditions, *Reforest*a, 7, 24-32.
- Šušić, N., M. Bobinac, I. Kerkez, A. Bauer-Živković, N. Vojinović, 2016: Height growth characteristics of one-year-old northern red oak seedlings (*Quercus rubra* L.): In full light conditions, *Reforesta*, 2, 32-38.

SAŽETAK

Querqus pubescens ima relativno široku rasprostranjenost u Europi, ali dominantne šume su prilično česte u južnoj Europi, dok su ograničene na tople mikroklimatske uvjete u srednjoj Europi. Na rubu Panonskog bazena,*Q. pubescens* uglavnom se nalazi na rubu svog autohtonog areala, u izoliranim populacijama koje imaju važnu ulogu u ispitivanju adaptivnog potencijala, posebno imajući u vidu da se predviđa da će šumsko-stepska i submediteranska klima biti dominantna klima u nekim regijama srednje Europe u budućnosti. Postoji vrlo ograničeno znanje o uspostavljanju i obnovi šuma *Q. pubescens* u današnjoj kontinentalnoj klimi. Velik broj istraživanja o obnovi šuma s ovom vrstom rađen je na području Mediterana, u uvjetima potpuno drugačije klime u usporedbi s kontinentalnom klimom koja je danas karakteristična za središnje dijelove Balkana. Ovo istraživanje pruža informacije o učinku tehnologije proizvodnje na uspjeh sadnica nakon sadnje na terenu u vrlo konkurentnim uvjetima i u uvjetima kontinentalne klime (Beograd, Srbija), a nakon sadnje na prostoru koji je u blizini sastojine iz koje potiče sjeme iz kojeg su proizvedene sadnice. Iako su sadnice golog korijena bile veće visine u rasadniku, kontejnerske sadnice bolje su preživjele i rasle na terenu. Ovo istraživanje je potvrdilo da visina sadnica ne mora nužno imati pozitivan utjecaj na preživljavanje i rast sadnica nakon sadnje u uvjetima intenzivne konkurencije korova. Bolji rast i preživljavanje sadnica nakon sadnje na terenu u korist kontejnerskih sadnica potvrđuje da sadnice s obloženim korijenom lakše podnose presadnju. Općenito, niska stopa preživljavanja za obje vrste sadnica (prosječno preživljavanje 47.60 %; kontejnerske sadnice 55.41 %; sadnice golog korena 41.41 %) može se ocijeniti kao posljedica nekonkurentnih sadnica i nedostatka kontrole korovske vegetacije.