Potential of new planting container in *Quercus robur* seedlings production - first report

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Abstract

Container production of forest seedlings needs constant improvement, so in the aim to test the new container type this research was conducted. *Quercus robur* seedlings were produced in the container made of natron paper and compared with seedlings produced in two commonly used container types in Serbia. *Q. robur* seeds were sown in the first week of November 2020 in a total of 30 containers (10 of each type). After the first growing season in the nursery, on November 2021, seedlings' morphological parameters (root collar diameter - RCD, height - H, dry weight of shoot (SDW) and root (RDW), seedling dry weight (SLDW), shoot to root ratio (S:R), sturdiness coefficient (SQ), dry weight of lateral roots (LRDW), percent of lateral roots (%LR), Dickson's quality index (QI), root-bound index (RBI) as RBI-diameter and RBI-volume, and rooting intensity (ROIN)) were compared using one-way ANOVA. Seedlings produced in the new container showed better morphological parameters such as H, SQ, SDW, RDW, SLDW, LRDW, QI and ROIN. Significant differences of seedlings from different containers were not detected for H, RCD, SQ, SDW, %LR, RBI-diameter, so we can conclude that seedlings produced in the new container type are similar with other container seedlings. Larger volume of these cells indicate use for *Quercus* species which have strong roots. Results obtained from the nursery promote use of the new container in forest seedlings production and testing at the field.

Keywords

Container seedlings; *Quercus robur*; Morphological parameters; Container types

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1 Introduction

From the mid second half of last century, container seedlings production took primacy in forest seedlings production. Numerous advantages of container seedlings like higher survival rate during production and later during transplanting and less transplant shock in comparison to bareroot seedlings (reviewed by Grossnickle and El-Kassaby 2016) promoted their use up today. Besides all the advantages there is also a negative aspect of seedlings with containerized roots. A whole range of container types in the world are made to avoid negative attributes that appear in production of seedlings with protected roots. Based on, containers can be divided to: containers planted with seedlings (degradable containers) and containers removed before outplanting (Tinus and McDonald 1979). Both basic container types further can be divided relative to their main characteristics: volume, shape, construction material, system and container design, seedlings density etc.

For most of the forest species smaller containers have been used, which are convenient to produce species with smaller seeds, slower growth and less-developed root system. However, for species with larger seeds, faster growth, and strong-developed root system such as oaks, it is best to use the larger containers. There is a lot of research that provides information about positive effect of larger container volume on seedlings height and root collar diameter inside *Quercus* species (Hanson et al. 1987; Cogliastro et al. 1995; Orešković et al. 2006; Jelić et al. 2014; Popović et al. 2014). Although height and root collar diameter are most used morphological parameters which represent features for seedling quality evaluation (Ivetić et al. 2016) and plant growth on the field (Grossnickle and MacDonald 2018), root system size cannot be marginalized. Also, root morphological parameters (mass, volume, lateral roots, etc.) which have a big role in overcoming planting stress and establishment after planting (Grossnickle 2005), should be taken in consideration while evaluating seedlings quality. Root deformations are the main problem in container seedlings production from the aspect of seedlings quality. Small containers cause root deformations (González-Rodríguez et al. 2011), but container stocktype mostly give good results in first years after oaks transplanting (Wilson et al. 2007). Differences can be detected in later periods, so McCreary (1995) reports better growth characteristics and response of field sown seedlings on fertilization than planted container blue oak seedlings.

The most commonly used container types in Serbia are from solid plastic: Jukosad, Bosnaplast, Pirosad and HIKO. Procurement costs for containers and container systems can be huge for smaller producers, so new and cheaper solutions are desirable. Presented container was made from natron paper on a multifunctional machine (MP-1570 U1) and it can be an easy solution. In the aim to test the new container for the purpose of forest seedlings production we choose *Q. robur* (*Quercus robur* L.) as species with high importance for forestry. Seedlings were produced in three different container types, including two commonly used containers and the new, and morphological parameters were tested after the first growing season in the nursery.

2 Material and methods

This research was conducted during 2021. in the nursery at the Faculty of Forestry - University of Belgrade (44.782572, 20.425504). *Q. robur* seeds (originated from north Serbia-Vojvodina region) were sown in the first week of November 2020 several days after collecting. Two types of commonly used containers from solid plastic were chosen in the aim to compare seedling production using new container from natron paper (Figure 1) and main characteristics of containers are shown in Table 1. Total of 30 containers (10 - Hiko V-265 (H-containers), 10 - Bosnaplast 18 (B-containers) and 10 containers made from natron paper with 20 cells - each cell was separated and 20 arrange together using plastic folia (P-containers)) were filled with mixture of Pindstrup® (Pindstrup Mosebrug, Denmark) and perlite (2:1) and in each cell were placed one seed. Germination was recorded in the third week of April 2021. and it was finished within 6 weeks. Seedlings were irrigated 3 to 5 times per week up to the last decades of August and foliar fertilization was provided two times per week during June and July (according to producer instruction, Fitogal® Galenika, Serbia).

Figure 1. Containers used in this research: container made from natron paper (left), Bosnaplast 18 (middle) and Hiko V-265 (right).

Table 1. Characteristics of used containers.

Traits	P-containers	B-containers	H-containers
Form	ring	hexagonal	square
Cell volume (cm3)	353	220	265
Depth (mm)	180	180	110
Density (n/m2)	400	440	368
Material	paper cardbord	hard plastic	hard plastic
Hole	hole bottom	bottom	bottom
Cell wall	slick	slick	slick
Dimension (mm)	250 x 200	320 x 215 x 180	352 x 216 x 150
Number of cells per container	20	33	28

At the end of the growing season in the first week of November 2021, 25 seedlings per treatment were lifted and transported in the laboratory (total of 75 seedlings). Seedlings' root was carefully separated from substrate under the gentle water jet, and fresh seedlings were measured for root collar diameter (RCD ± 0.1 mm) and height (H ± 0.1 cm). Seedlings were dried at 68 ± 2 °C during 48 hours (Ivetić 2013) and dry weight of shoot and root were determined, also as seedling's dry weight (SLDW). Shoot and root weights were measured on an electronic scale with an accuracy of 0.01 g. Shoot to root ratio (S:R) was calculated as the ratio between shoot dry weight (SDW) and root dry weight (RDW). Lateral roots (LRDW) were cut and separated from central root, so percent of lateral roots (%LR) were determined as percent of dry weight of lateral roots in comparison to total root dry weight. The sturdiness coefficient (1) was calculated according to Roller (1977), and the quality index (2) was calculated using Dickson et al. (1960) method. According to South and Mitchell (2005) we determined root-bound index (RBI) as RBI-diameter (3) and RBI-volume (4). Rooting intensity (ROIN) is calculated as the ratio between root weight and container volume (5) according to Endean and Carlson (1975).

(1) $SQ = \frac{H\ (cm)}{RCD\ (mm)}$

(2) $QI = \frac{SLDW(g)}{\left(\frac{H\ (cm)}{RCD\ (mm)}\right) + \left(\frac{SDW\ (g)}{RDW\ (g)}\right)}$

(3) $\text{RBI-diameter} = \frac{RCD\ (mm)}{container\ cell\ \ diameter\ (mm)} \times 100$

(4) $\text{RBI-volume} = \frac{RCD\ (mm)}{container\ cell\ volume\ (cm3)} \times 100$

(5) $ROIN = \frac{RDW\ (mg)}{container\ cell\ volume\ (cm3)}$

One-way ANOVA was used to test differences between mean values of measured characteristics between the treatments. Mean values were separated using Tukey post-hoc test, with significance level of $p<0.05$ ($\alpha=0.05$). All analyzes were performed in Statistica 7.0.

3 Results and discussion

Q. robur seedlings produced in P-containers were higher in comparison to seedlings produced in H-containers and B-containers, but at the same time in this group of seedlings were noticed higher variations and minimum to maximum range (Table 2). However, for seedlings from H-containers, the mean root collar diameter is slightly higher than the seedlings from other two types of containers. In comparison with results reported by Orešković et al. (2006) for *Q. robur* seedlings, our results are lower for seedlings' H, but similar in RCD. Popović et al. (2014) for *Q. robur* seedlings reported lower values for RCD, and slightly higher values for H compared to results presented in this paper. The analysis of variance showed that there is an insignificant difference between H and RCD and on the level of container type. Same results were given by Popović et al. (2014) for three types of containers – Bosnaplast 12, Bosnaplast 18 and Hiko V256 and the same species and age. Mariotti et al. (2015) are stating that type of containers did not affect RCD growth of *Q. robur* seedlings in their research. Same results for *Q. ilex* seedlings were reported by Jelić et al. (2014) in a study which investigated the influence of four different container types on seedlings growth. Seedlings from this research were larger in comparison to *Q. robur* seedlings reported by Devetaković et al. (2019) produced in Bosnaplast 12 containers a few years ago in the same nursery, which could be explained by the larger volume of the containers that we used in this research. Roth et al. (2011) produced *Q. robur* seedlings with different sizes of acorns in Bosnaplast 18 containers (same as in this study) in full light and in shade, so H of the seedlings produced in shade was higher for about 5 cm than seedlings in full light, and they concluded that H growth was high affected by light conditions while RCD were better at the full light conditions. In comparison to our results, mean height of our *Q. robur* seedlings is between values in full light and shade reported by Roth et al. (2011) for medium and large acorn seedlings.

Table 2. Morphometrical parameters of seedlings at the end of the first growing period in the nursery: H = height; RCD = root collar diameter; SQ = sturdiness coefficient; SDW = shoot dry weight; RDW = total roots dry weight; LRDW = lateral roots dry weight; SLDW = seedling dry weight; %LR = percent of lateral roots; S:R = shoot to root ratio; QI = quality index; RBI – DIA = root-bound index – diameter; RBI – VOL = root-bound index – volume; ROIN = rooting intensity.

Morphological parameters		**Container type**		
		Paper container - P	***Hiko V-265 - H***	***Bosnaplast 18 - B***
H	mean (SD)	18.64 (8.42)	17.24 (4.13)	17.10 (5.02)
	min-max	6.20 – 40.00	8.50 – 26.50	9.40 – 27.30
RCD	mean (SD)	4.95 (1.51)	5.35 (1.10)	4.85 (0.97)
	min-max	1.50 – 8.30	3.60 – 7.40	2.50 – 7.60
SQ	mean (SD)	3.66 (1.02)	3.27 (0.78)	3.56 (0.87)
	min-max	1.94 – 5.68	2.18 – 5.53	1.88 – 5.16
SDW	mean (SD)	1.80 (1.61)	1.32 (0.61)	1.43 (0.88)
	min-max	0.12 – 6.42	0.40 – 2.90	0.42 – 4.45
RDW	mean (SD)	2.94^{a} (2.44)	1.54^{a} (0.91)	1.13^{b} (0.46)
	min-max	0.44 – 9.90	0.68 – 4.43	0.37 – 1.86
LRDW	mean (SD)	0.30^{a} (0.27)	0.15^{a} (0.10)	0.12^{b} (0.08)
	min-max	0.01 – 1.13	0.02 – 0.49	0.01 – 0.27
SLDW	mean (SD)	4.74^{a} (3.93)	2.86^{a} (1.30)	2.56^{b} (1.13)
	min-max	0.58 – 14.53	1.23 – 5.90	0.83 – 5.66
%LR	mean (SD)	10.90 (6.99)	10.22 (6.04)	11.12 (8.87)
	min-max	3.21 – 28.63	2.17 – 28.51	0.60 – 40.81
S:R	mean (SD)	0.67^{a} (0.43)	0.97^{a} (0.45)	1.36^{b} (0.69)
	min-max	0.25 – 2.07	0.21 – 2.10	0.44 – 3.69
QI	mean (SD)	1.09^{a} (0.89)	0.71^{ab} (0.40)	0.54^{b} (0.24)
	min-max	0.12 – 4.25	0.30 – 2.05	0.14 – 0.95
RBI - DIA	mean (SD)	9.90 (3.02)	10.70 (2.21)	9.70 (1.94)
	min-max	3.00 – 16.60	7.20 – 14.80	5.00 – 15.20
RBI - VOL	mean (SD)	1.40^{b} (0.43)	2.02^{a} (0.42)	2.20^{a} (0.44)
	min-max	0.42 – 2.35	1.36 – 1.79	1.14 – 3.45
ROIN	mean (SD)	8.33^{a} (6.90)	5.83^{ab} (3.42)	5.13^{b} (2.09)
	min-max	1.24 – 28.05	2.56 – 16.72	1.68 – 8.45

All four weight parameters (SDW, RDW, LRDW, SLDW) are showing that seedlings produced in P-containers have a lot higher values, i.e. shoot, as well as root, separately and combined, are heavier (Table 2). Observing results for all three types of containers that we used in this research, SDW and RDW compared to other research for *Q. robur* (Orešković et al. 2006) was 2-4 times lower for SDW, and 5-11 times lower for RDW. In the same research, authors reported morphological parameters for *Q. petraea*, which were more similar to the results for *Q. robur* in this study. Devetaković et al. (2019) for seedlings grown in Bosnaplast 12 containers reported less values for

SDW and RDW. Roth et al. (2011) reported SLDW for seedlings that they produced from three different sizes of acorns is in the range of around 2.2-3.0 g for seedlings that were growing in shade, and that for the seedlings that were growing in full light that value is a lot higher (in the range of around 5.0-7.3 g). Results that we got are more comparable with the results that they got for the seedlings produced in shade. However, %LR is showing that the highest share of lateral roots in total root percentage have seedlings made in B-containers, but the least range between minimum and maximum values of %LR are for seedlings produced in P-containers (Table 2). Ivetić (2013) cites that for container seedlings optimum S:R ratio is 2:1, or even less, which is in pursuance with Barnett and Brissette (1986) who recommend RDW:SDW ratio between 0.45-0.65 to have balanced root and shoot seedling growth. According to Haase (2007) good quality container seedlings have shoot to root ratio 2:1, i.e. value ≤ 2. Seedlings in this research can be assessed as good from the point of S:R ration. From our analysis, the best mean S:R ratio have seedlings produced in P-containers (Table 2), while the worst, but still in range of good quality (Haase 2007), have seedlings from B-containers. Total value for this morphological parameter for all three types of container is 1.00, which is higher compared to results that Hanson et al. (1987) got for Northern Red Oak seedlings in six different types of containers. Devetaković et al. (2019) reported S:H ratio for *Q.robur* seedlings - 0.66, which is a similar value with seedlings produced in P-containers in this research. Contrary to our results, Roth et al. (2011) reported a lot lower values for S:R for seedlings that were produced in full light (around 0.21-0.31), while the ones that were produced in shade had slightly better S:R ratio (around 0.41-0.43), but compared to our results (Table 2), still lower. Analysis of variance showed that there is a statistical significance in the influence of container type on S:R ratio. Also, it showed that container type has a significant effect on QI and the highest values are for seedlings produced in P-containers - mean value 1.09 (Table 2).

South and Mitchell (2005) conducted research to see which root-bound index is related to outplanting survival for conifer species. For Pines they found that the RBI-diameter is 22% for smaller pots, and 19% for larger containers, while RBI-volume was 6% for larger and 12% for smaller pots. Authors are stating that for smaller containers lower survival is expected for a RBI-volume, but that survival should be higher for RBI-diameter. Related to previous statement they are suggesting that RBI-volume is a better quality indicator. In our research on *Q. robur* mean values for RBI – diameter are in range from 9.70 for seedlings produced in B-containers to 10.70 for seedlings in H-containers. RBI – volume (mean) has the lowest value for P-containers. Kolevska et al. (2020) for Pine species got RBI-diameter values around 5-6 times higher in comparison to our results, however they got RBI-volume similar values as ours.

According to Endean and Carlson (1975), who investigated how age (4-20 weeks) of Lodgepole pine seedlings affect root intensity (ROIN), the growth of seedlings decreased after reaching critical (“restricted”) ROIN value of 45 mg cm^{-3}, when total dry weight was reduced. In our analysis we found that ROIN mean value (8.33), as well as min-max range (1.24-28.05), are highest for seedlings produced in P-containers, which is the container with the largest volume that we used. Contrary to our research, Kolevska et al. (2020) for conifers reported higher ROIN values for containers with smaller volume. In comparison to our analysis values are up to 4 times lower. This can be explained that oak species need a lot more root growing space than Pines.

4 Conclusions

Q. robur seedlings produced in the new containers have slightly better morphological characteristics than seedlings from other two types of containers. Although RCD is lower for seedlings that have grown in the new type of container, the most parameters showed better values in comparison to commonly used container types. Given that oak species need more space to grow, a larger volume of the new containers is in their favor. Also, we can say that root parameters evidently are better in this type of container. Research conducted in the nursery suggests the possibility to promote use of the new paper containers in forest seedlings production and testing of their success in the field.

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