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Growth characteristics of three-year-old Turkey oak (*Quercus cerris* L.) seedlings from natural regeneration under a dense canopy stand

Original Article

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Abstract:

A morphometric analysis was conducted on three-year-old Turkey oak seedlings naturally regenerated from 2015 mast year in a degraded stand at Fruška gora on the site of pedunculate oak, European hornbeam and Turkey oak with limes (*Carpino betuli-Quercetum roboris* (Anić 59) Rauš 1971 var. geograf. *Tilia argentea* + *Tilia cordata* B. Jovanović & Tomić (1980) 1997). The stand overstory consists of Turkey oak and silver lime. After the first growing season, the height of the above-cotyledon-axis was between 8.6 and 44.1 cm, and the seedlings morphology was typical for shade conditions. The height growth increment in the second growing season was 0.7–6.1 cm, and 0.5–5.4 cm in the third growing season. The total height of the seedlings at the end of the third growing season was 13.0–47.0 cm, with 3–6 leaves and root collar diameter between 2.0 and 3.9 mm. In the closed canopy conditions, the three-year-old seedlings were are able to survive in large numbers while showing a specific norm of reaction in the first and the upcoming years. The one-flush growth is the basic trait of the height growth. The results are pointing out to the Turkey oak ability of ontogenetic adaptation in the dense canopy conditions. This is an important trait in the process of natural regeneration of mixed-species stands.

Key words:

shoot elongation, diameter growth, growth patterns, shade conditions, one-flush growth, ontogenesis

Apstrakt:

Karakteristike rasta trogodišnjih biljaka cera (Quercus cerris L.) iz prirodnog podmlatka u sastojini sa potpunim sklopom

Morfometrijski su analizirane trogodišnje biljke cera iz prirodnog podmlatka koji je nastao iz obilnog uroda 2015. godine u sastojini u kojoj dominira cer, na staništu lužnjaka, graba i cera sa lipama (*Carpino betuli-Quercetum roboris* (Anić 59) Rauš 1971. var. geograf. *Tilia argentea* + *Tilia cordata* B. Jovanović & Tomić (1980) 1997) na Fruškoj gori. U sastojini sa potpunim sklopom u prvoj godini nadkotiledona osa biljaka ima visinu u rasponu 8,6–44,1 cm i biljke imaju skiomorfni strukturni oblik. Prirast u visinu u drugoj godini je u rasponu 0,7–6,1 cm, a u trećoj godini 0,5–5,4 cm. U trećoj godini biljke su visoke u rasponu 13,0–47,0 cm, imaju 3–6 listova i prečnik korenovog vrata 2,0–3,9 mm. U uslovima sklopljene sastojine trogodišnji podmladak cera se održava u velikoj brojnosti, a biljke imaju specifičnu normu reakcije u rastu u visinu, u prvoj i narednim godinama. Osnovni tip rasta u visinu je monofazni rast. Rezultati ukazuju da cer ima sposobnost ontogenetskog prilagođavanja uslovima potpunog sklopa, što je važna osobina u procesu prirodnog obnavljanja mešovitih šuma u kojima je edifikator.

Ključne reči:

rast u visinu i debljinu; tipovi rasta; uslovi zasene; monofazni rast u visinu; ontogeneza

Introduction

Turkey oak (Fagaceae, *Quercus cerris* L.) is widely distributed tree species on the Balkan peninsula. In Serbia, it is usually found as edificator in zonal climax community with Hungarian oak (*Quercus frainetto* Ten.), in oroclimatic sessile oak belt and in many xerothermic oak forests on the southern border of Panonnian Plane. Monodominant Turkey oak forests may be found as mosaically distributed patches inside the zonal vegetation range (Jovanović, 1954; Tomić, 1991; Tomić & Rakonjac, 2013).

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Fig. 1. The structure of the stand with Turkey oak dominance on a site of pedunculate oak, European hornbeam and Turkey oak with lindens (*Carpino betuli-Quercetum roboris* (Anić 59) Rauš 1971. var. geograf. *Tilia argentea* + *Tilia cordata* B. Jovanović & Tomić (1980) 1997), GJ "Gvozdenjak lice", odeljenje 32 f (Photo: M. Bobinac, 2018).

The current stand condition of these forests in Serbia is unfavorable (Banković et al., 2009), so there is a need for improvement. The knowledge regarding the norm of reaction of edificators in these forests and the relationships that exist between them in juvenile stages of development when the plants are the most endangered is essential (Bobinac, 2011; Deligöz & Bayar, 2018). Some important edificators that are associated with Turkey oak, and considered more resistant to current climate change are Hungarian oak (Stojanović et al., 2014) and downy oak– *Quercus pubescens* L. (Pasta et al., 2016). In conditions of changing climate, the species from natural communities may be the most resilient and the maintenance of these species in forest stands is related to the their usage as well.

Kojić et al. (1994) classified Turkey oak and Hungarian oak as somewhere between shade intolerant (heliophytes) and intermediate shade tolerant (semi-sciophytes) species. Popović et al. (1997) have found that Turkey oak has somewhat wider ecological amplitude with respect to light compared to Hungarian oak. The research regarding the initial stages of development on sites of natural communities has shown that there is a specific norm of reaction in respect to height growth of Turkey oak in different growing conditions (closed canopy stands and fully illuminated cuttings). On the basis of these findings, height growth types were defined (Bobinac, 1997; 2001; Bobinac & Vilotić, 1998). The competitive ability of Turkey oak seedlings can be controlled by the means of silvicultural measures when the goal is the regeneration of more valuable associated oak species. This is related to the specific growth reaction of Turkey oak seedlings when released from shade conditions in the second year of growth (Bobinac, 2002). When sufficient light is available in the first years of development, the height growth is characterized by the occurrence of multi-flush growth (or lammas growth) in *Q. cerris* and some meso-xerophilous oaks such as Hungarian oak and xerophilous oaks such as holm oak (*Quercus ilex* L.) (Bobinac & Ballian, 2010; Šušić et al., 2019a). The growth patterns of *Q. cerris, Q. frainetto* and *Q. pubescens* seedlings in suboptimal growing conditions are similar, and thus their adaptive responses. However, Turkey oak seems to be more vigorous compared to the other two oak species (Šušić et al. 2019b).

The aim of this paper is to point out the growth characteristics of three-year-old Turkey oak seedlings that originate from natural regeneration in closed canopy conditions and contribute to knowledge about the regeneration ecology of this tree species.

Materials and Methods

The research was conducted in a degraded, mature stand in National Park "Fruška gora" in Management Unit "Gvozdenjak-Lice", compartment 32f. The overstory is dominated by Turkey oak and silver linden (*Tilia tomentosa* Moench). The understory is mostly dominated by silver linden and manna ash - *Fraxinus ornus* L. (**Fig. 1**). The total number of Turkey oak trees per hectare is 120 with mean diameter of around 50 cm and mean height of around 26 m. A small number of *Quercus virgiliana* (Ten.) Ten. trees was noted as well (Bobinac & Aleksić, 2007, 2016). The stand is located on moderately flat terrain at 170 m above sea level on loess bedrock on a site of pedunculate oak (*Quercus robur* L.), European hornbeam (*Carpinus betulus* L.) and Turkey oak with lindens (*Carpino betuli-Quercetum roboris* (Anić 1959) Rauš 1971. var. geograf. *Tilia argentea* + *Tilia cordata* B. Jovanović & Tomić (1980) 1997), (Tomić, 2013).

The morphometric analysis was performed on 150 seedlings that had normal, vertical height growth and originate from mast year of 2015. The seedlings were sampled from seedling cohorts with at least 50 seedlings per square meter. On these three-year-old

Table 1. Weather conditions in 2016, 2017 and 2018 compared to the 1981–2010 average for weather station Sremska Mitrovica (82 above sea level). Source: http://www.hidmet.gov.rs/

Year	T_{annual}	$T_{growing\ season}$	P_{annual}	$P_{growing\ season}$
2016	12.1	18.8	614.7	343.0
2017	12.2	19.2	533.2	338.6
2018	12.9	20.1	646.8	374.9
1981-2010	11.3	18.0	614.2	353.7

seedlings, the following biological traits were measured: (1) total height of seedlings in each year (Ht) – measured from the basis of the cotyledon leaves to the scars of the terminal buds (tip of the seedling); (2) root collar diameter (Drc) – measured just above the cotyledon scars and (3) total number of leaves (LN).

Total height of seedlings in each of the years was measured using the ruler with an accuracy of 0.1 cm. Root collar diameter was measured using a caliper with an accuracy of 0.1 mm. The height growth of each year was determined on the basis of the presence of terminal bud scars on the shoot axis in the way described by Bobinac (1994, 2001). The same trait was used for the classification of seedlings according to age and height-growth types during three years of development in the way described by Bobinac & Vilotić (1998). The following statistical parameters were calculated for the measured traits of the seedlings: arithmetic mean ($\bar{x}$), range (minimum, maximum), standard deviation (Sd), coefficient of variation (CV), skewness (skew) and kurtosis (kurt). The data analysis was performed using the R program package.

Data provided by the Republic Hydrometeorological service of Serbia (http://www.hidmet.gov.rs/index_eng.php) was used for describing the climatic conditions during the first three years of development of the seedlings (**Tab. 1**). The data from the nearest weather station (Sremska Mitrovica) was used.

During the 1981–2010 period, the mean air temperature in the growing season was 18.0 °C. The amount of precipitation in the growing season was 353.7 mm. During the period of growth of the seedlings, the mean temperature of the growing season was warmer by 0.8 °C than usual in 2016 and 2017, and by 2.1 °C in 2018. The amount of precipitation in the growing season was lower in 2016 and 2017 by 10.7 and 15.1 mm, respectively, and higher in 2018 by 21.2 mm compared to the 1981–2010 average.

Results and Discussion

The total height of one-year-old Turkey oak seedlings (Ht_2016) was between 8.6 and 44.1 cm with the mean value of 19.1 cm, coefficient of variation (CV) was 25.2%, and distribution was skewed to the right and leptokurtic. The height growth during the second and third growing season was poor. The mean height of the seedlings at the end of the second growing season was 21.9 cm, and 23.9 cm at the end of the third growing season. After the first growing season, the CV of height growth was reduced in the second and third growing season to 20% and 19%, respectively. The distribution was still skewed to the right and leptokurtic (**Tab. 2, Fig. 2**).

Table 2. The parameters of descriptive statistics of the analyzed sample of Turkey oak seedlings

Growth element	n	Mean	Min	Max	Sd	CV	skewnes	kurtosis
LN2018 [pcs]	150	4.13	3.0	6.0	0.82	19.9	0.183	-0.688
Drc_2018 [mm]	150	3.01	1.9	3.9	0.45	15.0	-0.152	-0.753
Ht_2016 [cm]	150	19.1	8.6	44.1	4.82	25.2	1.058	4.052
Ht_2017 [cm]	150	21.9	12.0	46.1	4.44	20.3	1.147	5.106
Ht_2018 [cm]	150	23.9	13.0	47.0	4.52	18.9	0.831	3.893
ih_2017–2016 [cm]	150	2.7	0.7	6.1	1.28	47.4	0.543	-0.486
ih_2018–2017 [cm]	150	2.1	0.5	5.4	1.15	55.3	0.918	0.212

Legend: LN– number of leaves, Drc– root collar diameter; Ht_2016; 2017; 2018 – total height; ih– current annual height increment

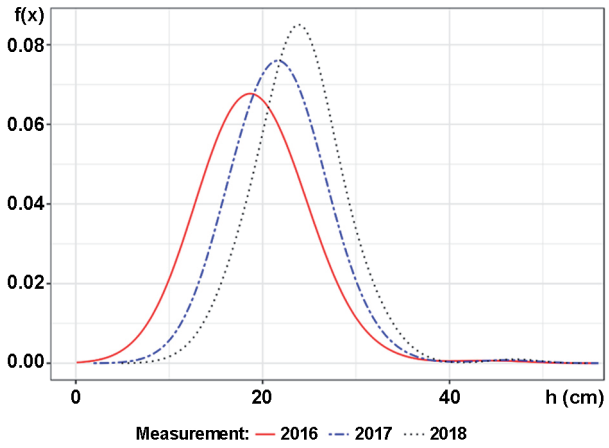

Fig. 2. The height distribution of analyzed Turkey oak seedlings in the first three growing seasons

The current annual height increment in the second growing season ranges from 0.7 to 6.1 cm, with the mean value of 2.7 cm (14.1% of the mean height of the seedlings after the first growing season). The CV is 47.4%, the distribution is skewed to the right and platykurtic. In the following year, the current annual height increment is reduced to 0.5–5.4 cm, with the mean value of 2.1 cm. The CV increases up to 55.3% in comparison to the previous growing season. The distribution of height increments in the third growing season is even more skewed to the right compared to the second growing season, and the shape of distribution shifts from platykurtic to leptokurtic (**Tab. 2**, **Fig. 3**).

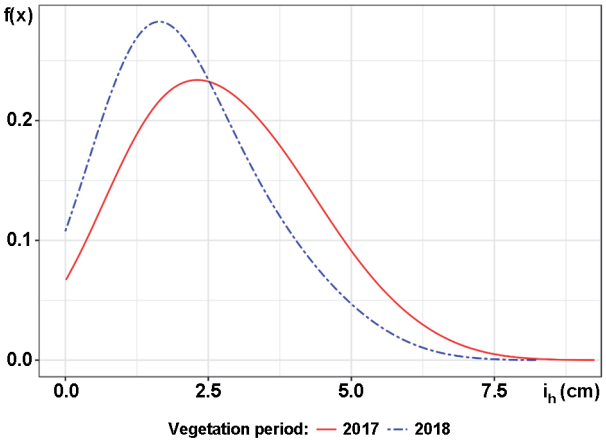

Fig. 3. The height increment distribution of analyzed Turkey oak seedlings in the second and third growing season (vegetation period)

The mean value of root collar diameter of the analyzed sample was 3 mm, with the CV of 15%, and distribution that is slightly skewed to the left and platykurtic. The number of leaves was between 3 and 6 with a mean value of 4.1, CV of 20%, and distribution that is slightly skewed to the right and platykurtic (**Tab. 2**).

Our findings indicate that two-year old Turkey oak seedlings are maintained in high numbers in closed canopy conditions and are not susceptible to powdery mildew (*Microsphaera alphitoides* Griff. et Maubl.) as shown in **Fig. 4**. This is contrary to results for *Quercus robur* L., provided by Bobinac (2011) and Bobinac & Karadžić (1994) where seedling mortality was very high in the second growing season due to a low shade tolerance of seedlings and high susceptibility to powdery mildew.

Despite the presence of wild ungulates in the area, a high number of seedlings (36–78 seedlings per m^2) is still present in the fourth growing season in well regenerated cohorts of Turkey oak that originate from 2015 mast year (**Fig. 5**).

The morphology of Turkey oak seedlings was typical for shade conditions. We observed pronounced elongation of above-cotyledon-axis (over 40 cm), low values of root collar diameter, (around 2.5 mm) and a small number of leaves (3–5) that is a typical reaction of heliophyte species to low light understory conditions of mature stands. The survival strategy of heliophilous oaks in shade conditions highly depends on the plants ability to express rapid height growth in order to reach out of the shade (Grime, 1981). During the second and third growing season, the seedlings expressed slow height growth. Turkey oak showed a specific norm of reaction in closed canopy conditions so the height growth type of the seedlings could basically be classified as one-flush growth type (**Fig. 6**). The growth pattern in closed canopy conditions is different in pedunculate oak where seedlings express multi-flush growth, and up to five flushes in a growing season (Bobinac, 2011).

In the given closed canopy conditions, Turkey oak seedlings express rapid height growth in the first growing season due to relatively large acorn – for example, acorn width and length is significantly higher in Turkey oak compared to Hungarian and downy oak (Šušić et al., 2019b). Thanks to resources stored in acorn, Turkey oak attained a mean height of 19.1 cm in analyzed conditions. However, in the following growing season, when acorn resources were depleted and the growth was more dependent on assimilation, height growth slowed down so the annual height increment was reduced to a mean of 2.7 cm and this trend continued in the third growing season when the annual height increment was 2.1 cm on average. Of the total height at the end of the third growing season, 80% was attained in the first growing season.

However, the fact that a large number of seedlings is still present after three years, shows that Turkey oak is able to survive in these conditions in

Fig. 4. Two-year-old Turkey oak cohort originating from 2015 mast year. Management unit "GJ Gvozdenjak-Lice", compartment 32f (Photo: M. Bobinac, 2017)

Fig. 5. Number and appereance of Turkey oak cohort originating from 2015 mast year in the third year of development. Management Unit "Gvozdenjak-Lice", compartment 32f (Photo: M. Bobinac, 2018)

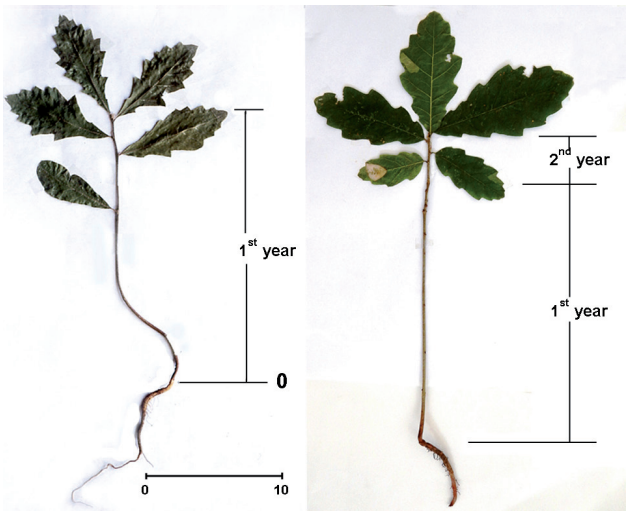

Fig. 6. Phenotype of Turkey oak seedlings with one-flush height growth in closed canopy conditions in the first year (left, Bobinac & Vilotić, 1998) and the second year of development (right)

juvenile stages of development. A relatively wide norm of reaction of *Q. cerris* seedlings was observed in Hungary as well (Ádám et al., 2018).

The extent of natural regeneration of Turkey oak in closed canopy conditions cannot be a priori considered as the element for planning the natural regeneration of stands; rather, it should be used as an element of restoration of more valuable edificators (Bobinac, 2002).

The shade tolerance of Turkey oak in juvenile stages of development and its rather slow reaction to improved light conditions (Bobinac, 2002), can be used in silviculture when the competitive ability of Turkey oak should be kept under control in order to promote regeneration of more valuable edificators such are Hungarian, downy or pedunculate oak.

Conclusion

In the closed canopy conditions, three-year-old Turkey oak cohorts maintain themselves in large numbers. The seedlings show a specific norm of reaction regarding height growth in the first and the following years. The basic height-growth type is one-flush growth type that is the result of the uniform growing conditions characterised by low light conditions in the understory of mature stands.

The height growth of one-year-old Turkey oak seedlings (Ht_2016) was between 8.6 and 44.1 cm with the mean value of 19.1 cm. The current annual height increment was reduced after the first growing season. It dropped down to 0.7–6.1 cm (2.7 cm on average) in the second and 0.5–5.4 cm (2.1 cm on average) in the third growing season. Around 80% of the total height growth of the seedlings measured at the end of the third year was attained during the first growing season when acorn resources were available.

The results reveal that Turkey oak seedlings show ontogenetic ability to adapt to the closed canopy conditions. This enables the species to survive in mixed species stands. In addition, the ability can be used in a nature-based silvicultural strategy to withhold the competitiveness of Turkey oak and give advantage to other, more valuable oak edificators such as Hungarian, downy or pedunculate oak.

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