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GROWTH CHARACTERISTICS OF ONE-YEAR-OLD HUNGARIAN OAK SEEDLINGS (*Quercus frainetto* Ten.) IN FULL LIGHT CONDITIONS*

ZNAČAJKE RASTA JEDNOGODIŠNJIH SADNICA HRASTA SLADUNA (*Quercus frainetto* Ten.) U UVJETIMA POTPUNOG SVJETLA*

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SUMMARY

In silviculture, the characteristics of growth of seedlings in relation to light conditions are an important indicator of the success of natural regeneration. The paper shows the growth characteristics of one-year-old Hungarian oak seedlings in full light conditions in a field experiment conducted in 2016 in the nursery of the Faculty of Forestry in Belgrade. Four hundred seedlings were analyzed and classified according to the number of shoot growth flushes into three growth types: one-flush growth, two-flush growth and three-flush growth type. Within the analyzed four hundred seedlings, 39.8% belonged to the one-flush growth type, 58.2% to the two-flush growth type, and only 2.0% of the seedlings to the three-flush growth type. The one-flush growth seedlings have less leaves and lower values of height, root collar diameter and total leaf area, but they are characterized by a higher mean height of the primary axis (the height of the first growth flush), compared to the multi-flush growth seedlings. This is pointing out to different growth characteristics in the initial stage of development and during the growing season between different types of seedlings.

KEY WORDS: seedling growth types, single flushing, multiple flushing, root collar diameter, leaf area

INTRODUCTION
UVOD

For successful natural regeneration of oak stands, the key stage of development is represented by one-year-old seedlings that are the basis for further growth of the young crop. The norm of reaction of different growth elements of one-year-old oak seedlings, especially height growth, in relation to light conditions, can be very wide and only a small part of it is optimal in terms of the species ability to outcompete other plant species and successfully regenerate.

The multi-flush growth during the growing season (polycyclism) is a characteristic trait for genus *Quercus* L. (Bobinac et al. 2012). In Serbia, the occurrence of multi-flush growth is recorded in one-year-old seedlings of

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different native oak species and discussed primarily from the silvicultural aspect: in pedunculate oak (Bobinac 1994; Bobinac 2011; Bobinac and Karadžić 1994; Pap et al. 2013); Turkey oak (Bobinac 1997; 2001; Bobinac and Vilotić 1998); Hungarian oak (Šušić 2017) and sessile oak (Krstić et al. 2018).

According to Harmer (1990; 1992), the shoot elongation in *Q. robur* and *Q. petraea* occurs in a rhytmic pattern of rapid shoot extension altering with periods of inactivity when the terminal bud is developing. In woody plants, multi-flush growth is better expressed in juvenile trees compared to adult trees (Borchert 1976). There is a strong relation between the annual shoot elongation of the plants and the number of height-growth flushes in the growing season (Phares 1971; Collet et al. 1997). Due to the young crops ability to adapt to environmental conditions, multi-flush growth enables it to maintain the aimed height faster, so the regeneration period can be shortened in the conditions of high control of the natural regeneration process in pedunculate oak forests (Bobinac, 1999; 2011). However, multiple flushing may cause the occurrence of different deleterious stem forms in young plants of many woody species (Cline and Harrington 2007). The higher susceptibility to the powdery mildew (*Erysiphe alphitoides* Griff. et Maubl.) of pedunculate oak leaves from later growth flushes in the growing season and the dieback of flushes is related to the multi-flush growth as well (Bobinac 2011; Pap et al. 2012).

The results of many studies suggest that the light conditions are an important factor that affects the height growth of different oak species in the first growing season and it was noted that the growth is differentiated under different light conditions (Bobinac 1997; 2011; Bobinac and Ballian 2010; Cardillo and Bernal 2006; Jarvis, 1964; Kolb et al. 1990; Ovington and MacRae 1960; Phares, 1971; Ponton et al. 2002; Roth et al. 2011; van Hees, 1997; Ziegenhagen and Kausch 1995).

There is little information about the growth characteristics of Hungarian oak in the initial stage of development in Serbia, particularly regarding the multi-flush growth as a characteristic trait of genus *Quercus* L. Having this in mind, the aim of this paper was to investigate the growth characteristics of one-year-old Hungarian oak seedlings in full light conditions and contribute to a better understanding of the ecology of the species.

MATERIALS AND METHODS
MATERIJALI I METODE

Research object – *Objekat istraživanja*

In the nursery of Faculty of Forestry in Belgrade (coordinates: 44^0 78'25,23"N, 20^0 42'55,19" E), a field experiment was set in the autumn of 2015 at 125 m a.s.l. on the area of 10 x 1.5 m. The acorn sowing was carried out in approximately 5 x 15 cm spacing. The acorn was collected a few days before sowing in a stand of Hungarian and Turkey oak close to Kraljevo (coordinates: 43^0 68'45.16"N, 20^0 54'62.99" E).

According to Nonić (2016), the soil in the nursery is characterized by low to moderate alkaline pH value (7.64–8.43), sufficient provision of N, P and K and favorable mechanical composition. The research area is characterized by the zonal forest vegetation at the southern boundary of Pannonia, *Quercetum cerridis-virgilianae* (Jov. et. Vuk. 77) that is in direct contact with the zonal forest vegetation of Hungarian and Turkey oak (Tomić 1991).

In 2016, the mean annual and the mean air temperature of the growing season was 1.3°C higher compared to the 1981–2010 average (12.5°C). As for precipitation, the annual amount as well as the amount of precipitation in the growing season of 2016 were higher by 74.1 mm (10.7%) and 30.1 mm (7.7%) respectively compared to the 1981–2010 average (690.9 mm). The data were collected from the website of Republic Hidrometerological Service of Serbia***.

Sampling and the analysis of the plant material – *Uzorkovanje i analiza biljnog materijala*

At the end of the growing season 2016, 400 normally developed plants were randomly sampled from the area of the field experiment and used for morphometric analysis. Plants were measured by non-destructive analysis. The measured morphological parameters were the total height of seedlings (Ht) and the height of growth flushes (H_{1-n}) using the ruler with the accuracy of 0.5 cm and the root collar diameter (Drc) measured just above the cotyledon scars using the Vernier caliper with the accuracy of 0.1 mm. For the identification of the cotyledon scars, the soil was previously prepared. The growth flushes (shoot phases) determination was based on the number of scars of juvenile buds on the annual axis, in the way described by Bobinac (1994; 2001), i.e. the occurrence of proleptic shoots was determined in the way described by Gruber (1992) (Figure 1).

The total number of leaves (LN) was determined for every phase of growth (growth flush). Three leaves were collected per growth flush and herbarized separately. The leaves were scanned and their leaf area was measured in ImageJ software (Schneider et al. 2012). The leaf area was used for the calculation of the average leaf area in the growth flush. The determination of the total leaf area of every growth flush was done in the following way: the mean value of the measured leaf area, based on three collected leaves was multiplied with the total number of leaves of the flush. The determination of the total leaf area for the whole seedling (TLA) was done by adding the values of leaf areas of all the growth flushes belonging to the specific seedling.

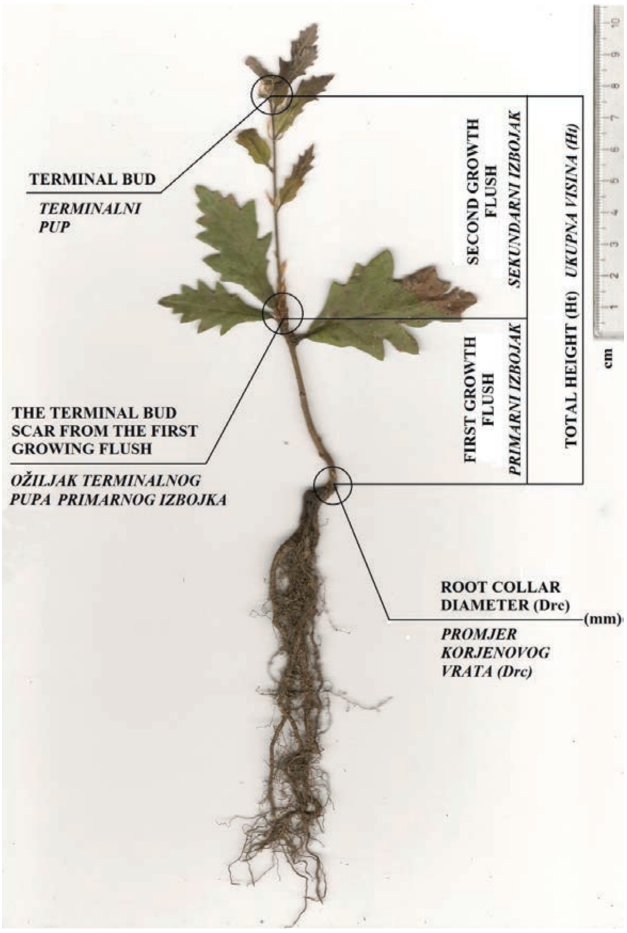

Figure 1. The analyzed morphological parameters on a Hungarian oak seedling in the first growing season.
Slika 1. Analizirane morfološke značajke na sadnici sladuna u prvoj vegetaciji.

Statistical analysis – *Statistička analiza*

Based on the number of growth flushes, all the plants were differentiated into one-flush growth (single flushing – with only the primary axis formed), two-flush growth and three-flush growth seedlings (with the season shoot growth formed in a multi-flush manner), i.e. the height growth types were determined (Bobinac 1997). The descriptive statistics parameters were determined for the analyzed elements of one-year-old Hungarian oak seedlings (total height, multi-flush growth, root collar diameter, number of leaves, total leaf area) for all the seedlings and growth types: arithmetic mean ($\bar{x}$), standard deviation (s_d), median (med), coefficient of variation (c_v), minimum (min), maximum (max), skewness (skew) and kurtosis (kurt). Before the testing of arithmetic means, the testing of sample variances was conducted for one-flush growth and multi-flush growth seedlings using the F test. The testing of arithmetic means was conducted using the t-test assuming unequal variances and the distribution comparison was done using the Kolmogorov-Smirnov test. The testing was done using the programme package *stats* in R environment (R Core Team, 2018). The distributions of growth elements were modelled with Weibull's probability density function using the Harter and Moore method (1965), in R environment.

RESULTS
REZULTATI

When all 400 seedlings are observed (Table 1), the root collar diameter (Drc) is the least variable growth element with the coefficient of variation of 20.0%, while the total leaf area (TLA) is the most variable growth element (c_v = 53.3%). All analyzed growth elements are characterized with distributions that have a right symmetry that is less expressed in the number of leaves (LN) and the root collar diameter compared to the total height (Ht) and the total leaf area. All growth elements have a leptokurtic distribution except the LN growth element that is platykurtic.

During the growing season, the height growth of Hungarian oak seedlings was developed through up to three phases (shoots) of growth. Therefore, three seedling growth types were defined: one-flush growth, two-flush growth and three-flush growth type.

In the analyzed sample, 39.8% of the seedlings belonged to the one-flush growth, 58.2% to the two-flush growth and only 2.0 % to the three-flush growth type (Figure 2).

Since only a small number of seedlings with three flushes was recorded, they were observed together with two-flush

Table 1. Descriptive statistics of the analyzed growth elements of one-year-old Hungarian oak seedlings at the level of the complete sample.
Tablica 1. Deskriptivna statistika analiziranih značajki rasta jednogodišnjih biljaka sladuna na razini ukupnog uzorka.

Statistical parameters *Statistički parametri*	Growth element *Značajka rasta* Drc [mm]	Ht [cm]	TLA [cm²]	LN [kom]
n – Sample size *Veličina uzorka*	400			
$\bar{x}$ – Arithmetic mean *Srednja vrijednost*	3.7	9.7	80.2	7.9
med – Median *Medijana*	3.5	9.0	70.3	8.0
s_d – Standard deviation *Standardna devijacija*	0.7	3.1	42.7	3.2
c_v – Coefficient of variation *Koeficijent varijacije*	20.0	32.3	53.3	40.4
min – Minimum *Minimum*	2.0	5.0	18.0	2.0
max – Maximum *Maksimum*	6.6	22.5	320.6	19.0
skew – Skewness *Koeficijent asimetričnosti*	0.527	1.112	1.083	0.322
kurt – Kurtosis *Koeficijent spljoštenosti*	0.561	1.073	1.998	–0.617

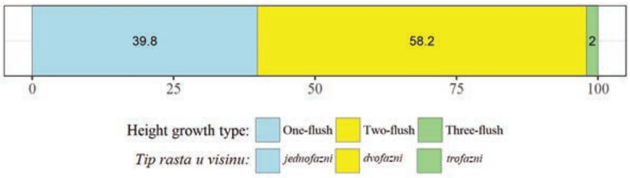

Figure 2. The percentage of different height growth types in one-year-old Hungarian oak seedlings.
Slika 2. Postotno učešće tipova rasta u visinu kod jednogodišnjih biljaka sladuna.

growth seedlings in the category "Multi-flush growth" in the further statistical analysis.

The one-flush growth seedlings have smaller total height, root collar diameter, number of leaves and total leaf area as well as smaller minimal and maximal values of these growth elements. However, they have a higher mean height of the primary axis (the height of the first flush), compared to the seedlings with multi-flush growth (Table 2).

The results of testing the variances of samples of one-year-old Hungarian oak seedlings with one-flush and multi-flush growth showed significant differences between all the analyzed growth elements at the significance level of $p < 0.05$. However, there are no significant differences in the variances of the samples of the root collar diameter (Drc) and the height of the first growing flush (H_1), at the significance level of $p < 0.01$ (Table 3).

The results of t-test show that between the means of the analyzed growth elements of the one-flush and multi-flush growth plants, a highly significant difference exists, at the level of $p < 0.001$ (Figure 3).

The parameters of the descriptive statistics of the root collar diameter (Drc) of the multi-flush growth plants are pointing out to somewhat higher variability and more expressed asymmetry compared to the one-flush growth seedlings (Table 2). The positions and shapes of models of distribu-

Table 2. The parameters of descriptive statistics of the analyzed growth elements of different height growth types of Hungarian oak one-year-old seedlings.
Tablica 2. Deskriptivna statistika analiziranih značajki elemenata rasta kod različitih tipova rasta jednogodišnjih biljaka sladuna u visinu.

Statistical parameters *Statistički parametri*	Drc [mm]		H_1 [cm]	Ht [cm]		TLA [cm²]		LN [kom]	
	One-flush *Jednofazni rast*	Multi-flush *Višefazni rast*	Multi-flush *Višefazni rast*	One-flush *Jednofazni rast*	Multi-flush *Višefazni rast*	One-flush *Jednofazni rast*	Multi-flush *Višefazni rast*	One-flush *Jednofazni rast*	Multi-flush *Višefazni rast*
n – Sample size *Veličina uzorka*	159	241	241	159	241	159	241	159	241
$\bar{x}$ – Arithmetic mean *Srednja vrijednost*	3.5	3.8	5.5	7.3	11.3	44.1	104.0	4.7	10.0
med – Median *Medijana*	3.4	3.5	5.5	7.0	10.5	42.5	100.7	5.0	10.0
s_d – Standard deviation *Standardna devijacija*	0.6	0.8	1.3	1.1	3.0	12.4	38.8	1.1	2.2
c_v – Coefficient of variation *Koeficijent varijacije*	18.8	20.2	23.0	14.4	26.7	28.1	37.3	24.3	22.3
min – Minimum *Minimum*	2.0	2.2	3.0	5.0	5.5	18.0	26.1	2.0	4.0
max – Maximum *Maksimum*	5.5	6.6	9.0	10.5	22.5	76.1	320.6	8.0	19.0
skew – Skewness *Koeficijent asimetričnosti*	0.247	0.573	0.203	0.217	0.857	0.343	1.046	0.521	0.537
kurt – Kurtosis *Koeficijent spljoštenosti*	–0.019	0.528	–0.372	–0.098	0.677	–0.326	3.460	0.036	0.799

Table 3. The results of F test for the differences in the variances of the samples between the one-flush and multi-flush growth seedlings.
Tablica 3. Rezultati F testa razlika u varijancama uzoraka biljaka sa jednofaznim i višestrukim rastom.

Growth element *Značajka rasta*	σ_1^2 / σ_2^2	p-value *p-vrijednost*
Drc	0.743	0.0438
H_1	0.687	0.0110
Ht	0.122	< 0.0001
TLA	0.265	< 0.0001
LN	0.102	< 0.0001

Table 4. Results of Kolmogorov-Smirnov test of comparing distributions of one-year-old Hungarian oak seedlings with one-flush and multi-flush growth.
Tablica 4. Rezultati Kolmogorov-Smirnov testa za usporedbu distribucija jednogodišnjih sadnica sladuna s jednofaznim i višestrukim rastom u visinu.

Growth element *Značajka rasta*	|D|	p-value *p-vrijednost*
Drc	0.1784	0.004496
H_1	0.56009	< 0.0001
Ht	0.71142	< 0.0001
TLA	0.8829	< 0.0001
LN	0.81088	< 0.0001

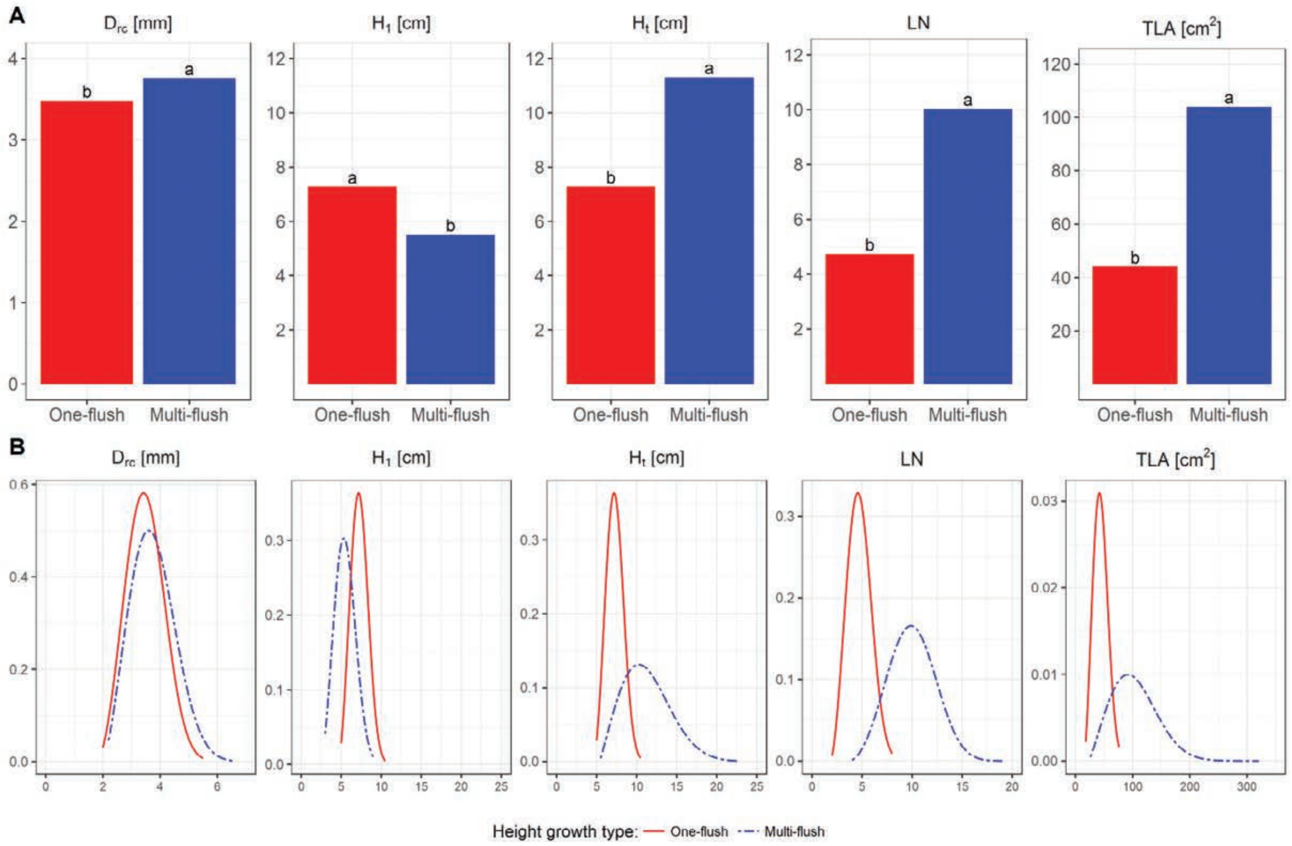

Figure 3. A — The average values of root collar diameter (Drc), height of the first growth flush (H1), total height (Ht), number of leaves (LN) and the total leaf area (TLA) of one-year-old Hungarian oak seedlings and the significant groups according to t-test between the types of seedlings with one-flush and multi-flush growth.

B — The distributions of the growth elements of one-year-old Hungarian oak seedlings modelled by Weibull probability density function.

Slika 3. A — Prosječne vrijednosti promjera korjenovog vrata (Drc), visine primarnog rasta (H1), ukupne visine jednogodišnjih biljaka sladuna (Ht), broja (LN) i ukupne površine listova (TLA), kao i rezultati t-testa.

B — Distribucije značajki rasta modelirane funkcijom gustoće vjerojatnosti po Weibull-u za jednogodišnje biljke sladuna.

tions of the root collar diameter are clearly pointing out the difference between the one-flush and multi-flush growth seedlings (Figure 3).

The height of the one-flush growth seedlings are higher by 1.8 cm on average compared to the height of the first growing flush (shoot) in multi-flush growth plants, with somewhat lower absolute variability (s_d) and the relative variability (c_v) that is lower by twofold. The asymmetry is slightly positive that is shown by the models of distributions. However, the total height of multi-flush seedlings is 55% higher compared to the one-flush growth seedlings. The absolute variability is almost threefold, and the relative variability twofold higher and the right asymmetry is more pronounced that can be seen in the Weibull's models of distributions (Table 2, Figure 3).

Compared to one-flush growth seedlings, the number of leaves of multi-flush growth Hungarian oak seedlings was by twofold higher, and the total leaf area was 2.3 times higher, on average. The absolute variability of the number of leaves of multi-flush growth seedlings was higher by twofold and of the total leaf area by threefold with the more pronounced right asymmetry of total leaf area compared to the one-flush growth seedlings. The models of distributions of the number of leaves and the total leaf area are clearly supporting the characteristics shown by the descriptive statistics (Table 2, Figure 3).

The nonparametric Kolmogorov-Smirnov test confirmed the significant differences between the distributions of one-flush and multi-flush growth of one-year-old Hungarian oak seedlings of all analyzed growth elements (Table 4).

DISCUSSION
RASPRAVA

In the conditions of the field experiment, the Hungarian oak seedlings expressed the multi-flush growth in the first growing season. In one-flush growth seedlings, the growth stops when the primary axis (the first flush) finishes its growth in the spring, while in multi-flush growth seedlings, the growth continues throughout the summer, with the elements of different individual reaction.

Although the growing conditions were uniform in the experiment, the variances of the first growth flush (H_1) of one-flush and multi-flush growth seedlings differed significantly ($p = 0.0110$, Table 3).

The one-flush growth seedlings finished their growth in the growing season when the primary axis was established while the multi-flush growth plants obtained their first growing phase. The differences in the means are pointing out towards the specific reaction of these two collectives of seedlings and that the multi-flush growth in Hungarian oak one-year-old seedlings was an induced trait in the way that was observed in pedunculate oak (Bobinac 1994). The variances of the total height of the seedlings, the number of leaves and the total leaf area are significantly different between the one-flush growth and multi-flush growth seedlings. This is pointing out to the different reaction of the seedlings to the same growing conditions. The higher total height, a larger number of leaves and the total leaf area of seedlings with multi-flush growth are the result of the induced apical activity, i.e. its prolonged activity in the growing season, compared to the one-flush growth seedlings.

The knowledge of the norm of reaction of Hungarian oak seedlings to different light conditions, i.e. different environmental conditions can give the information about the evolutionary biology and ontogenetic adaptation. This can provide the answers of the fundamental importance for the silviculture of these forests.

Multi-flush growth is typical for pedunculate oak and can be related to the optimum growing conditions (Le Hir et al., 2005). According to Spiess et al. (2012), the long term drought stress affect the multi-flush growth in pedunculate oak plants and the activation of growth flushes can be prolonged for the period after the drought stress. Sever et al. (2018) observed a five-flush growth in two-year-old pedunculate oak both in plants from the drought stress treatment (conducted in the first half of the growing season) and in optimum growth conditions, with the plants from the drought stress treatment prolonging their flushing for the post-drought period. This is pointing out to the adaptability of pedunculate oak to different growing conditions during the growing season. According to Roy et al. (1986), the occurrence of multi-flush growth is the result of the adaptation to higher levels of photosynthetically active radiation. Therefore, the multi-flush growth of the pedunculate oak young crop is an important indicator of the success of the natural regeneration in the pedunculate oak forests (Bobinac 2011). The multi-flush growth was used in the projection of the fungicide protection of young crop in the process of natural regeneration of pedunculate oak (Pap et al. 2012), and was recommended for defining the effects of the fungicide protection application (Pap et al. 2013).

Different oak species are expressing different adaptive abilities depending on the light conditions. For instance, multi-flush growth was recorded in full light and xerothermic conditions while in the conditions of the stand closure only plants with one-flush growth type were recorded (Bobinac 1997; 2001; Bobinac and Vilotić 1998). According to Bobinac (1997), one-flush growth type, two-flush growth type in full light conditions and one-flush growth type in stand closure conditions all make one homogenous statistical group regarding the mean total height, statistically differing only from three-flush growth type from full light conditions. However, when root collar diameter and the number of leaves are observed, there are significant differences between all the growth types, so the multiple flushing plants have higher values of root collar diameter and number of leaves. This indicates that even when there are no significant differences between the groups in terms of total height, the number of flushes is a good indicator of the general vigour of one-year-old Turkey oak seedlings. Similar conclusions were drawn for two-year-old Turkey oak seedlings, as well (Bobinac 2001).

According to Bercea (2013), in the group cuts conditions, during the first growing season, the second flush occurred only in 0.3% of the total number of seedlings analyzed; the plants finished their height growth until 30 May in the growing season with the average height of 11 cm (min 3, max 18 cm) with 3–5 leaves, and the second flushing was rare in Turkey oak seedlings as well. According to Bobinac (2002), the one-year-old young crop of Turkey oak, formed in the stand closure light conditions reacts slowly to improved light conditions. This characteristic of Turkey oak can be used in controlling its competitive ability when successful regeneration of other oak species that are growing with Turkey oak is needed.

In pedunculate oak one-year-old seedlings, multi-flush growth was observed as a mass phenomenon in different site and light conditions and the seedlings had up to five flushes of growth (Bobinac 2011; Pap et al. 2013). The strategy of heliophilous oak species in shade conditions is related to fast height growth in the first year in order to grow out of the shade zone (Grime, 1981). The heliophytes are developing in the multiple stress conditions and generally their life-form is characterized with short stems and internodiums (Stevanović and Janković, 2001). According to Bobinac (2011), that kind of growth is expressed in pedunculate and Turkey oak young crop in favourable light conditions created after seeding fellings in the stage of forming the primary axis (the first growth flush) that precedes the multiple flushing. The same conclusion, that the primary axis is shorter in plants with multiple flushing, compared to one-flush growth plants are confirmed in this Hungarian oak study in the field experiment. Also, the multi-flush growth is present on mass scale in the pedunculate and Turkey oak young crop in mentioned favourable conditions. This multi-flush young crop maintains higher values of height growth compared to the one-flush growth that was confirmed in this Hungarian oak field experiment study as well.

The importance of multiple flushing of different oak species (sessile, pedunculate and Turkey oak) in the early stages of ontogenetic development, as an ecological adaptation to different environmental conditions was investigated from the aspect of physiology (Masarovičova, 1989), morphology (Masarovičova and Požgaj, 1988) and the results are important for silviculture of oak forests.

The knowledge about the growth characteristics, and thus of the multi-flush growth, is very important for the process of seed regeneration in different conditions. For instance, in the growing conditions of the research of Ovington and MacRae (1960), sessile oak mean height of one-year-old seedlings was the lowest in the conditions of the highest light intensity (11.6 cm), while in the most shaded conditions the plants had a height of 17.1 cm. The similar pattern was found by Jarvis (1964) and Ponton et al. (2002) where the mean height of one-year-old sessile oak seedlings is higher going from relative light intensity of 20 to 100% and 8 to 100%, respectively.

The results from previously cited studies are pointing out that different oak species are showing different growth reactions regarding height growth in different light conditions. This may be in relation to the multi-flush growth. The knowledge about the height growth characteristics, i.e. its norm of reaction enables the creation of conditions that favours the most desired part of the norm of reaction from the aspect of silviculture in the natural regeneration from seed using suitable silvicultural measures.

The presented results regarding Hungarian oak one-year-old seedlings are contributing to a better understanding of the ecology of the species in the initial stage of development. The results are in compliance with the growth characteristics that are found in some other oak species in well illuminated conditions. Therefore, they can be considered as a good basis for further investigations of optimal growth of this valuable, meso-xerothermic oak species that should have greater management importance in the territory of Serbia and southeastern Europe, having in mind the climate changes.

CONCLUSIONS
ZAKLJUČCI

On the basis of 400 analyzed one-year-old Hungarian oak seedlings in the growing conditions of the field experiment in full light conditions, the following can be concluded:

1. The mean height of one-year-old Hungarian oak seedlings is 9.71 cm; mean root collar diameter 3.65 mm; the mean number of leaves per seedlings 7.9 and the mean total leaf area 80.18 cm^2;
2. The height growth of Hungarian oak seedlings developed through up to three height growth flushes (growth phases) and three growth types of seedlings were defined: one-flush growth, two-flush growth and three-flush growth type;
3. In the analyzed sample, 39.8% of the plants belonged to one-flush, 58.2% to two-flush and only 2.0% to three-flush growth type;
4. The one-flush growth seedlings have less leaves and lower values of height, root collar diameter and total leaf area, but they are characterized by a higher mean height of the primary axis (the height of the first flush of growth), compared to the multi-flush growth seedlings. This is pointing out to different growth characteristics in the initial stage of development and during the growing season between different types of seedlings;
5. The multi-flush growth seedlings are characterized with higher variability of analyzed elements compared to the one-flush seedlings, and the positions and shapes of the models of distributions are clearly pointing out to the differences between the one-flush and multi-flush growth seedlings;
6. The phenotypic variability based on the presence of multi-flush growth shows that, from the silvicultural aspect, it is important to define the conditions that favour the occurrence of multi-flush growth of Hungarian oak since it has a significant influence on total height, root collar diameter, number of leaves and the total leaf area of one-year-old seedlings.

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SAŽETAK

U radu su prikazane značajke rasta jednogodišnjih biljaka sladuna u uvjetima potpunog svjetla u poljskom pokusu 2016. godine. U odnosu na višegodišnji prosjek (1981.–2010. godine) srednja temperatura zraka u vegetacijskom razdoblju 2016. godine bila je veća za 1.3˚C, a količina oborina za 30.1 mm.

Broj ožiljaka terminalnih pupova na jednogodišnjim biljkama sladuna (Slika 1), definira broj faza rasta u visinu na temelju kojega su izdvojeni tipovi rasta biljaka: biljke s jednofaznim, dvofaznim i trofaznim rastom. U analiziranom uzorku, 39,8% biljaka pripada jednofaznom tipu rasta, 58,2% dvofaznom, a svega 2,0% trofaznom tipu rasta (Slika 2). S obzirom na mali broj biljaka s trofaznim rastom u visinu, sve biljke su podijeljene u dvije skupine: biljke sa jednofaznim i biljke sa višestrukim rastom u visinu (Tablica 2). Postoje statistički značajne razlike u varijancama uzoraka kod svih značajki rasta između biljaka s jednofaznim i višestrukim rastom na razini $p < 0,05$, a na razini $p < 0,01$ između srednjih vrijednosti svih analiziranih elemenata rasta između biljaka s jednofaznim i višestrukim rastom. Primjetno je da raspodjela svih elemenata rasta varira između dvije definirane skupine biljaka. S obzirom na visinu primarnog rasta (H_1), biljke s jednofaznim rastom su po apsolutnoj varijabilnosti nešto manje varijabilne, a po relativnoj duplo manje varijabilne od biljaka s višestrukim rastom, s blago pozitivnom asimetrijom. Što se tiče ukupne visine, biljke sa višestrukim rastom su znatno varijabilnije kako glede apsolutne varijabilnosti, tako i relativne varijabilnosti i s više izraženom desnom asimetrijom u odnosu na biljke s jednofaznim rastom. Kod biljaka s višestrukim rastom, apsolutna varijabilnost broja listova je dvostruko veća, a ukupne površine listova trostruko veća s izraženom desnom asimetrijom u usporedbi s biljkama s jednofaznim rastom. Postoje značajne razlike između raspodjela biljaka s jednofaznim i višestrukim rastom u visinu.

Biljke s jednofaznim rastom imaju manju ukupnu visinu, manji promjer korjenovog vrata, manji broj i ukupnu površinu listova, ali se odlikuju većom srednjom visinom primarnog rasta u odnosu na biljke sa višestrukim rastom, što ukazuje na različite značajke rasta u početnoj fazi i tijekom vegetacijskog razdoblja između ovih tipova biljaka.

KLJUČNE RJEČI: tipovi rasta biljaka, jednofazni rast, višestruki rast, promjer korjenovog vrata, površina listova