

Height growth characteristics of one-year-old northern red oak seedlings (*Quercus rubra* L.) in full light conditions

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Abstract

In this nursery experiment, 100 one-year-old northern red oak seedlings were measured at the end of the 2016 growing season. Measured growth elements were: total height, root collar diameter and total leaf area. All seedlings were classified according to the presence of polycyclism into four types: one-flush growth, two-flush growth, three-flush growth, and four-flush growth type. The number of new flushes (shoots) is a good indicator of total height, root collar diameter and total leaf area.

Keywords

Northern red oak; Polycyclism; Flush growth; Height; Root collar diameter; Leaf area

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1 Introduction

About 100 species originating from North America are registered in Serbia, with 18 used in forestry, (Perović and Cvjetičanin 2015). Northern red oak (*Quercus rubra* L.) is one of three economically and ecologically most important allochthonous tree species in Central Europe and has the characteristics of fast-growing species with high levels of production of dendromass. By the mid-twentieth century Northern red oak was introduced in Serbia, mainly in the region of Vojvodina (Petrović 1951). In the wider area of Serbia it may represent a very important economic, ecological and aesthetic tree species on sessile oak habitats (Vučković et al. 2008). It is also recommended for introduction on the habitats of Hungarian and Turkey oak (Isajev et al. 2013, Stojanović et al. 2006) and it is a potential species in biomeliorations (Krstić and Vojinović 2002). According to Isajev et al. (2013), there is a special significance of the red oak introduction to the habitats of Hungarian and Turkey oak in Serbia, considering the high degree of acclimatization, an exceptional vitality, condition, adaptability and naturalization of this species.

Knowledge of ecology or the relationship between forest trees and

environmental conditions has a great importance to the growth and regeneration of forests (Bunuševac 1951). The ecology of initial phases of plants (seedlings) is much less researched than the ecology of adult plants, but for the species ecology and its survival, the ecology of the youngest stages of development is crucial (Janković 1995). The selection of regeneration method and projection of regeneration cuttings, requires knowledge of growth characteristics and seedling development of young trees in different environments (Bobinac 2011).

Polycyclism, i.e. the polyphase formation of annual shoots, is a characteristic trait of *Quercus* species (Bobinac et al. 2012). Multiflush growth in height is a well expressed trait in juvenile plants, several flushes of growth can be expected during one vegetation period, but with plant aging, multiflush growth stops and adult trees are characterized most often with only one new flush growth during the vegetation period (Borchert 1976). According to previous research in Serbia in nursery conditions, at one-year-old Northern red oak seedlings polycyclism was identified in four flushes of growth (Krstić and Vojinović 2002). A determinant ecological factor that affects emergence of multiflush growth in red oaks is light intensity so the plant in terms of full light exhibit several flushes, unlike the shade conditions, when they are usually from only one flush (Phares 1971). The same results were found with European oak specie whose fruit matures in the second year, Turkey oak (*Quercus cerris* L.) (Bobinac 1994, 2001; Bobinac and Vilotić 1998).

The aim of this study is to determine the growth patterns of red oaks (polycyclism) grown in full light and classifying types of plants in relation to the present polycyclism to the point of specific recommendations, relevant to the process of growing.

2 Material and methods

Red oak seedlings (1+0) are produced in the nursery, at the Faculty of Forestry in Belgrade in 2016. Land in the nursery is characterized by low to moderate alkaline pH value (7.64 to 8.63), sufficient provision of nitrogen, phosphorus and potassium and favorable mechanical composition (Nonić 2016). Breeding measures consisted of weed control and occasional watering in the summer. The growing season of 2016 is characterized by mean monthly air temperature of 18.1°C and rainfall of 561.0 mm.

At the end of the growing season, 100 seedlings from the middle of the nursery bed were measured. A total height (Ht), the number of phase shoots and their length, with an accuracy of 0.5 cm and root collar diameter (Dk) with an accuracy of 0.1 mm, were measured for each plant. Definition of different flushes (shoots) was performed following Bobinac (1994, 2001). Three leaves were collected from every plant and shoot, then herbarised. The leaves were scanned, and using software ImageJ (Figure 1) their total area (TLA) was measured. Total leaf area was determined at the level of each shoot and at the level of the whole plant.

Statistical analysis was performed using descriptive statistics and LSD test for testing the differences between mean values of the growth elements of different types of plant growth, compared to the present polycyclism.

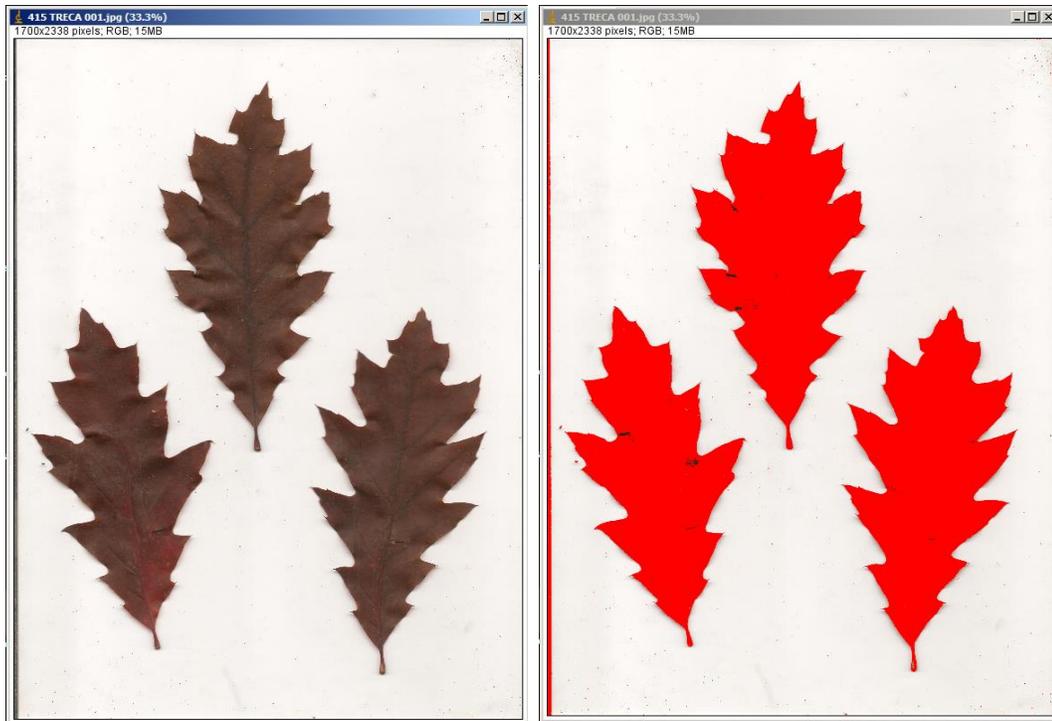


Figure 1. Leaves scanned and prepared for measurement.

3 Results

Within 100 northern red oak seedlings, four growth types were defined: one-flush growth, two-flush growth, three-flush growth, and four-flush growth. Since there was only one seedling with four-flush growth type, only seedlings from other growth types were statistically analyzed. Elements of growth of 1+0 northern red oak seedlings are shown in Table 1.

Table 1. Results of descriptive statistics for northern red oak elements of growth.

Statistical parameter	Growth element		
	Dk [mm]	Ht [cm]	TLA [cm ²]
n		100	
x	4.2	16.4	245.6
Sd	0.98	5.57	114.3
Kv%	23.3	33.9	46.5
min	2.7	7.5	81.7
max	7.0	33.5	622.5

Growth of northern red oak seedlings at the level of different growth types is shown in table 2.

Table 2. Results of descriptive statistics for northern red oak seedlings of different growth types.

Statistical parameter	Growth type								
	One-flush growth			Two-flush growth			Three-flush growth		
	Growth element								
	Dk	Ht	TLA	Dk	Ht	TLA	Dk	Ht	TLA
	[mm]	[cm]	[cm ²]	[mm]	[cm]	[cm ²]	[mm]	[cm]	[cm ²]
n		29			55			15	
x	3.7	10.7	149.5	4.2	17.2	251.5	5.2	23.3	394.5
Sd	0.75	2.67	44.3	0.77	3.41	90.0	1.19	4.30	102.7
Kv%	20.0	24.9	29.6	18.4	19.7	35.8	22.9	18.4	26.0
min	2.9	7.5	81.7	2.7	10.0	110.4	3.1	18.0	280.3
max	5.9	21.0	279.6	5.9	27.0	512.2	7.0	32.5	622.5

As more flushes occur on a seedling, the higher are the mean values of root collar diameter, total height and total leaf area (Table 2). One-flush growth type seedlings are characterized by the lowest mean values of all three growth elements, two-flush growth type with intermediary and three-flush growth type with the highest mean values of growth elements (Figure 2). The four-flush growth type seedling is characterized with a root collar diameter of 7.0 mm, total height of 35.5 cm and those are the maximum values at the level of all 100 seedlings for these two growth elements. Total leaf area of this seedling is 472.2 cm². It should be noticed that the leaves from the fourth flush were defoliated earlier before the collection for the analysis so they couldn't be measured.

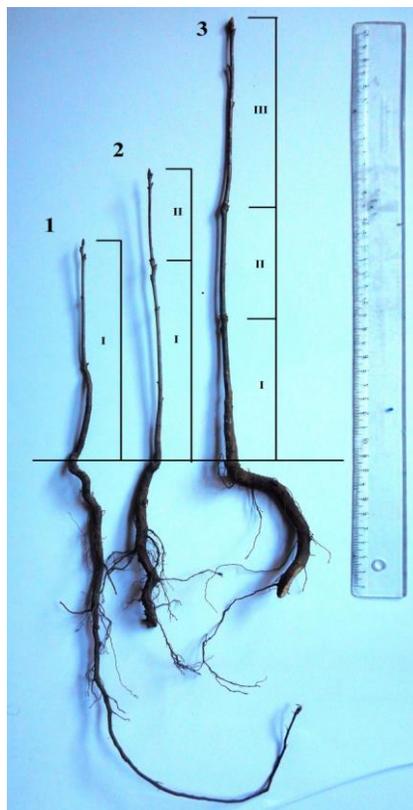


Figure 2. One-flush (left), two-flush (in the middle) and three-flush (right) growth type in height of northern red oak.

Results of analysis of variance for growth elements: root collar diameter, total height and total leaf area are shown in Table 3.

Table 3. Analysis of variance for growth elements: root collar diameter, total height and total leaf area.

Root collar diameter (Dk)	SS	df	MS	F	P-value
Between groups	20.534	2	10.267	14.640	0.0000
Within groups	67.324	96	0.702		
Total	87.858	98			
Total height (Ht)	SS	df	MS	F	P-value
Between groups	1696.638	2	848,319	75.124	0.0000
Within groups	1084.043	96	11.292		
Total	2780.682	98			
Total leaf area (TLA)	SS	df	MS	F	P-value
Between groups	601681.9	2	300840,5	45.105	0.0000
Within groups	640303.2	96	6669.8		
Total	1241984.1	98			

The testing of mean values for three height growth types is done using the LSD test. For all three growth elements (root collar diameter, total height, total leaf area), there was a statistically significant difference between height growth types (one-flush, two-flush and three-flush growth type) at the level of significance of 0.01. Only for root collar diameter at the level of one-flush growth type VS two-flush growth type there was a significant difference between the means at the level of 0.05.

4 Discussion and conclusion

Elements of growth of northern red oak are very variable in literature because there are several factors that affect the growth, including growing measures. In the first year after germination, the growth of northern red oak is affected by acorn size (Popović et al. 2015) which lasts in the first three years of growth (Gall and Taft 1973), by temperature (Farmer 1975) and fertilization (Gall and Taft 1973; Phares 1971). It is noticed that there are early and late flushing types of northern red oak. It may be important having in mind that the early flushing type has better early height growth and late flushing type is more resistant to spring frosts (Gall and Taft 1973).

In our research, seedlings were produced extensively. Acorns used were a mix of different mother trees and were of variable size. Breeding measures used were only mechanical weed control and periodical watering during the summer. That is probably the reason why our elements of growth are generally lower than in other researches where more intensive breeding measures were applied (Farmer 1975; Krstić and Vojinović 2002; Phares 1971). However, the growth pattern of seedlings remained the same in the first year after germination in full light conditions and that's in compliance with other authors. In nursery conditions, with more intensive breeding measures, Krstić, Vojinović (2002) concluded 4 flushes of growth as well, but with higher values. Phares (1971) concluded polycyclism in full light conditions and only one-flush growth in shade. According to Farmer (1975), full light conditions have a positive effect on total height and air temperature is an important factor as well. It affects the appearance, frequency and how fast new flushes grow with temperature optimum

between 23°C and 29°C. This author suggests that one-flush growth type and two-flush growth type plants should be rogued in the production of northern red oak.

Our results confirm the growth pattern of northern red oak considering polycyclism. One-flush seedlings are characterized by the lowest mean values of total height, root collar diameter and total leaf area. Three-flush seedlings are characterized with the highest values of these growth elements which is confirmed by results of the LSD test. The same pattern exists with maximum values of these growth elements, except for root collar diameter where both one-flush growth type and two-flush growth type have the same minimum values of root collar diameter.

Since the number of new flushes (shoots) is a good indicator of total height, root collar diameter and total leaf area, it can be recommended as a supplementary criteria in the evaluation of production success considering the production goals. Also, it may be recommended as an indicator of favorability of growing conditions for a successful natural regeneration of northern red oak stands in conditions of highly controlled regeneration process, similar to that in common oak stands (Bobinac 2011; Pap et al. 2013).

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