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FLUSHING VARIABILITY OF PEDUNCULATE OAK (*QUERCUS ROBUR* L.) IN THE PROVENANCE EXPERIMENT IN CROATIA

SANJA PERIĆ*, JOSO GRAČAN*, BOJANA DALBELO-BAŠIĆ**

*Forestry Research Institute, Jastrebarsko, Cvjetno naselje 41, HR-10450 Jastrebarsko, Croatia
**Faculty of Forestry, Svetošimunska 25, HR – 10000 Zagreb, Croatia

The provenance experiment of Pedunculate Oak, with a total of 16 provenances, was established in spring 1988 in the Gajno locality, in the Forest Office Karlovac. The experiment was established in a completely randomised block design in four repetitions with 400 2+0 old seedlings per provenance. The flushing investigation of Pedunculate Oak started in spring 1992. Monitoring was repeated in 1993 and 1994. Significant differences in the flushing variability range were observed between and within provenances. The variability of flushing in 1992 was three weeks, in 1993 four weeks, and in 1994 it was six weeks. A more detailed research of the flushing of Pedunculate Oak started in 1996, in seven flushing phases. The results of this research have shown the existence of differences in flushing time between and within provenances in all seven phases.

Key words: Pedunculate Oak provenances, variability of flushing phases, Croatia

INTRODUCTION

Pedunculate Oak (*Quercus robur* L.) is one of the most valuable and most important broadleaf tree species, not only in Croatia but in Europe as well. Of the total forested areas of Croatia, 1/10 are Pedunculate Oak forests and those located in the eastern part of Croatia achieve their optimum. A large area of dispersion as well as an extensive variability of edaphic and hydrological conditions under which the Pedunculate Oak grows have caused significant variability in its morphological and physiological characteristics (Krstinić 1996). Research on the growth success of different provenances of Pedunculate Oak in European coun-

tries (Germany, Austria, Denmark) began as early as the start of the twentieth century (Birger 1921, Ciesler 1923), whereas in Croatia they began much later (Gračan 1986, Gračan and Perić 1993, Gračan and others 1995). Flushing as a feature of the physiological character has been studied by many scientists (Nikodem 1977, Hayek 1909, Hesmer 1955, Šafar 1966, Stojković 1991, Gračan and others 1991, 1993, 1995). Literature contains various data on the beginning of flushing in provenance tests. For instance, the difference in the beginning of flushing in early and late Pedunculate Oak vary from 7 days (Hendrich 1973) to 2-4 weeks (Šafar 1966).

The aim of the research is to monitor the survival and growth success of different Pedunculate Oak provenances in Croatia as well as to monitor flushing in seven phenophases[1] in order to establish the time difference of flushing in early and late Pedunculate Oak.

MATERIAL AND METHODS

Pedunculate Oak flushing was monitored in a test including 16 provenances. The test was established in the spring of 1988 at the Gajno locality (Karlovac Forest Administration, Forest Office Jastrebarsko) in a randomised block design in four replications with 400 plants per provenance, i.e. 100 per replication. Basic data on the Pedunculate Oak provenance are shown in Table 1. Survival registra-

Table 1. The general data about Oak provenances

Number	Provenances	Altitude	Longitude	Elevation
1	Motovun	45°20′	13°50′	90
2	Skakavac	45°29′	15°42′	112
3	Orlovac	45°33′	15°44′	112
4	Velika Gorica	45°40′	16°10′	98
5	Novska	45°02′	16°55′	143
6	Lipovljani	45°26′	16°49′	143
7	Okučani	45°11′	17°10′	95
8	Đurđenovac	45°34′	18°08′	97
9	Guševac	45°13′	18°29′	96
10	Spačva	44°56′	18°50′	85
11	Gunja	44°57′	18°49′	86
12	Moroviæ	45°02′	19°11′	82-85
13	Dubica	45°17′	16°44′	98
14	Zdenački gaj	45°37′	17°04′	160
15	Ključevi	45°11′	17°21′	95
16	Vrbanja	45°01′	18°59′	85

[1] Further on "phase"

Photo 1. Phases of Pedunculate Oak flushing (Photo: S. Perić)

tion as well as diameter and height measurements were conducted during the spring of 1988. The data were processed using the variance analysis method and

Table 2. Mean, maximum and minimum monthly and annual air temperatures (Meteorological Station Jastrebarsko)

Temperatures in °C	Year	Months												
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yearly
Mean	1997	-1.2	3.2	5.9	7.2	16.1	19.3	19.7	19.5	15.2	8.6	4.9	2.3	10.1
	1998	2.6	4.3	4.7	11.9	15.2	19.9	20.7	21.6	15.2	10.8	3.2	-3.9	10.5
	1999	1.7	0.8	7.6	11.1	16.1	19.2	20.8	20.3	17.8	11.3	3.1	0.5	10.6
Maximum	1997	5.0	18.5	21.5	20.5	30.0	31.0	31.5	30.0	30.0	26.2	22.5	12.6	31.5
	1998	15.5	23.0	20.5	25.6	29.1	34.2	32.5	34.0	29.0	22.0	19.0	5.4	34.2
	1999	13.0	19.1	20.5	25.0	31.0	30.0	34.5	33.0	29.5	25.5	21.0	13.0	34.5
Minimum	1997	-10.6	10.5	-3.5	-4.5	2.1	4.0	9.2	9.0	2.0	-3.0	-7.5	-6.5	-10.6
	1998	-8.7	-9.5	-6.0	-1.5	3.2	5.5	7.3	5.0	3.5	-0.4	-8.5	-16.5	-16.5
	1999	-6.0	-14.5	-2.0	0.6	6.2	7.6	12.5	10.0	8.8	1.0	-11.2	-14.0	-14.5

the F – test. Monitoring of the flushing of the Pedunculate Oak plants began in spring 1992 and was continued in the following years. Since 1997 the flushing of plants of different provenances has been monitored in seven phases. The first phase is the phase of overwintering, characterised by sleeping buds. In the second phase the buds are swollen and prolonged, whereas in the third phase they begin to open and the first green is visible. The fourth phase is characterised by the appearance of the first bent leaves which are more clearly visible in the fifth phase. In the sixth phase the leaves are formed but still obviously twisted lengthwise and in the seventh phase they become completely developed, smooth and wide. The 7 phases of Pedunculate Oak flushing is shown in Photograph 1. Monitoring of the Pedunculate Oak flushing from beginning to end in seven phases was conducted in 1997 starting on April 7 until May 28 (11 times), in 1998 from April 6 to May 5 (11 times) and in 1999 from March 22 to May 31 (12 times). In every monitoring the plants were categorised into flushing phases. The monitoring was conducted every 4-8 days. The data were sorted by provenance, blocks, phases and time of monitoring. During the three years of monitoring, a total of 16,500 tests were conducted.

Since the data acquired are very complex and numerous, tests were conducted for the data acquired for phases 1 - 2 and 6 – 7 for 1997, 1998 and 1999. The monitoring results are shown in diagrams (method of descriptive statistics) so as to enable better visibility of certain tendencies and the definition of a correct statistical hypothesis. The percentage of polylinear charts for plants in phases 1, 2, 6 and 7 are shown by year and monitoring time for all provenances. After the descriptive statistics, we began to conduct the analysis by monitoring phases 1 and 2, i.e. the end of phase 1 and the entering into phase 2 which represents the start of the flushing process. The polylinear charts which represent the transition from phase 1 to phase 2 and phase 6 into phase 7 are similar to the distribution of the survival function which was the basis for using the survival analysis. Because of its relative simplicity, the parameterless Kaplan-Meir method was chosen to evaluate the survival

distribution function. This method is based on the time distribution function of phase 2 (i.e. the number of days elapsed from the beginning of the monitoring – April 7 1997; April 4 1998; March 22 1999). This number of elapsed days is marked with "t", and $S_i(t)$ is the probability that the monitored (i-t) provenance is still in phenophase 1 after "t" or more days since the beginning of monitoring. The advantage of this method lies in the possibility of testing the equality hypothesis $S_i(t)$, i=1....16, i.e. on the equality of the survival function by provenance. The statistical hypothesis on the equality of the probability that phase 2 begins "t" days from the beginning of monitoring (March 22 1999) was, for all 16 provenances, tested using the Log-rank and Wilcoxon tests. The assumption was that all provenances were to start flushing at the same time. Because of the connection of flushing with air temperature, Table 2 shows the maximum, minimum and mean values of air temperature by month for 1997, 1998 and 1999. The data were registered in the meteorological station in Jastrebarsko.

RESULTS AND DISCUSSION

Table 3 shows the survival results of Pedunculate Oak provenances in 1998. The average percentage of survival was relatively high at 86.78%, and in absolute terms varies from 77.75% in the Ključevi provenance to 93.0% in the Orlovac provenance. Alongside Orlovac, a high survival percentage is noted in the Guševac

Table 3. Survival of Pedunculate Oak plants at Gajno locality (1998)

No.	Provenances	Blocks				Mean value
		I	II	III	IV	
1	Motovun	92	93	82	77	86.00
2	Skakavac	89	79	92	93	88.25
3	Orlovac	97	87	94	94	93.00
4	Velika Gorica	84	91	92	80	86.75
5	Novska	96	99	89	75	89.75
6	Lipovljani	90	94	97	79	90.00
7	Okučani	77	93	81	94	86.25
8	Đurđenovac	83	89	81	82	83.75
9	Guševac	93	91	85	95	91.00
10	Spačva	85	89	82	74	82.50
11	Gunja	83	96	91	87	89.25
12	Mitrovica	90	89	94	76	87.25
13	Dubica	89	94	75	90	87.00
14	Zdenački gaj	88	98	79	79	86.00
15	Ključevi	69	96	84	62	77.75
16	Vrbanja	87	89	83	77	84.00
Mean values		87.00	91.69	86.31	82.13	86.78

(91%), Lipovljani (90%) and Novska (89.75%) provenances. Table 4 shows the results of the diameter and height measurement for 1998. According to these data the largest mean diameter was recorded in the provenances Đurđenovac (41.4 mm), Okučani (40.9 mm), Spačva (40.9 mm) and the largest mean height was recorded in the Spačva (397.7 cm), Đurđenovac (394.6 cm) and Okučani (392.3 cm) provenances. Table 5 shows the F – test results for diameter and height measurements by provenance. The F – test results for the diameter is 1.89. Since this is identical to the value of the F – distribution for 5% taken from the Tables, we can discard the hypothesis of diameter equality with a 5% risk. Significant differences have been noted in the 5% margin between the mean heights in different provenances. Since the p- value is 1.3%, we can consider the height differences to be significant. Knowledge acquired from forest tree breeding confirms these data, since plant height is under stricter genetic control than diameter which is largely influenced by planting density.

Table 4. Diameter and heights growth of Pedunculate Oak at Gajno locality (1998)

No.	Provenances	Diameter, (mm)					Heights (cm)				Mean value
		Bloks				Mean value	Bloks				
		I	II	III	IV		I	II	III	IV	
1	Motovun	24.18	28.00	34.13	27.97	28.57	234.14	292.22	326.96	245.32	274.66
2	Skakavac	32.78	28.25	36.73	34.85	33.15	292.62	263.13	350.43	338.14	311.08
3	Orlovac	38.81	42.18	38.14	39.47	39.65	365.56	383.22	362.35	383.47	373.65
4	Velika Gorica	40.16	41.00	35.21	32.71	37.27	351.45	374.37	365.92	340.51	358.06
5	Novska	31.63	41.87	46.32	30.51	37.58	319.70	411.07	415.52	280.95	356.81
6	Lipovljani	42.77	30.99	41.39	40.89	39.01	401.28	319.23	404.49	400.03	381.26
7	Okučani	55.33	31.33	38.53	38.54	40.93	482.48	331.11	355.98	399.56	392.28
8	Đurđenovac	48.94	43.01	35.77	37.75	41.37	441.30	417.37	372.94	346.94	394.64
9	Guševac	28.54	35.43	38.77	38.95	35.42	284.27	341.73	370.66	359.49	339.04
10	Spačva	43.33	41.05	42.50	36.61	40.87	397.28	407.47	415.76	358.22	394.68
11	Gunja	47.30	41.04	32.54	39.02	39.98	479.14	364.54	337.10	379.26	390.01
12	Mitrovica	39.71	26.71	40.19	32.41	34.76	370.00	236.03	400.16	312.64	329.71
13	Dubica	29.45	29.51	34.65	33.86	31.87	280.56	298.30	349.79	351.62	320.07
14	Zdenački gaj	40.97	39.89	37.73	34.00	38.15	371.56	421.43	398.39	328.85	380.06
15	Ključevi	41.91	36.77	31.11	36.34	36.53	412.43	383.31	343.14	314.39	363.32
16	Vrbanja	46.20	32.37	35.43	35.38	37.35	404.54	304.52	324.41	295.79	332.32
mean		39.50	35.59	37.45	35.58	37.03	368.02	346.82	368.38	339.70	355.73

Table 5. F-test values of diameter and heights for Pedunculate Oak, locality Gajno (1998)

Source of variability	Degrees of freedom	F-values	
		Diameter, mm	Heights, cm
Provenances	15	1.89	2.37
Blocks	3		
Error	45		

*F 5% =1.89
**F 1%= 2.46

The research results of flushing variability through phases (1-7) are shown through descriptive statistics and the function of survival distribution. The graphical illustration of the percentage values of phases 1 and 2 in Figures 1, 2 and 3 show transition tendencies from phase 1 to phase 2 for individual provenances for 1997, 1998 and 1999. This shows a divergence for the provenances Gunja, Velika Gorica and Novska from the other 13 provenances. The Gunja provenance remains in phase 1 the longest. 98% of the plants of the Gunja provenance were still in phase 1 on April 30 1997, 82% on April 28 1998 and 81% on April 26 1999. During the monitored years the Gunja provenance shows a mild transition from phase 1 to phase 2 by the end of April. A homogeneus transition in a very short interval (5 to 7 days) is visible from April 30 to May 5 in 1997, April 28 to May 5 in 1998 and April 26 to May 3 in 1999. The Velika Gorica and Novksa provenances have an oscillation in the transition from phase 1 to phase 2. From the polylinear charts for the monitored years, it is visible that the Velika Gorica provenance has a slower transition into phase 2 than the Novska provenance. The shortest transition into phase 2 for all three years is present in the Đurđenovac provenance. Over 90% of all plants from this provenance entered phase 2 from April 7 to March 30 in 1997 (23 days), April 6 to April 28 in 1998 (18 days) and from March 22 to April 7 in 1999 (17 days). Figures 1, 2 and 3 show the flushing variability in the transition from phase 1 to phase 2. According to Stojković (1997), variability can be of a continued or discontinued nature. With continued variability, the transition is gradual, whereas with discontinued variability the transition is sharp. Gradual transi-

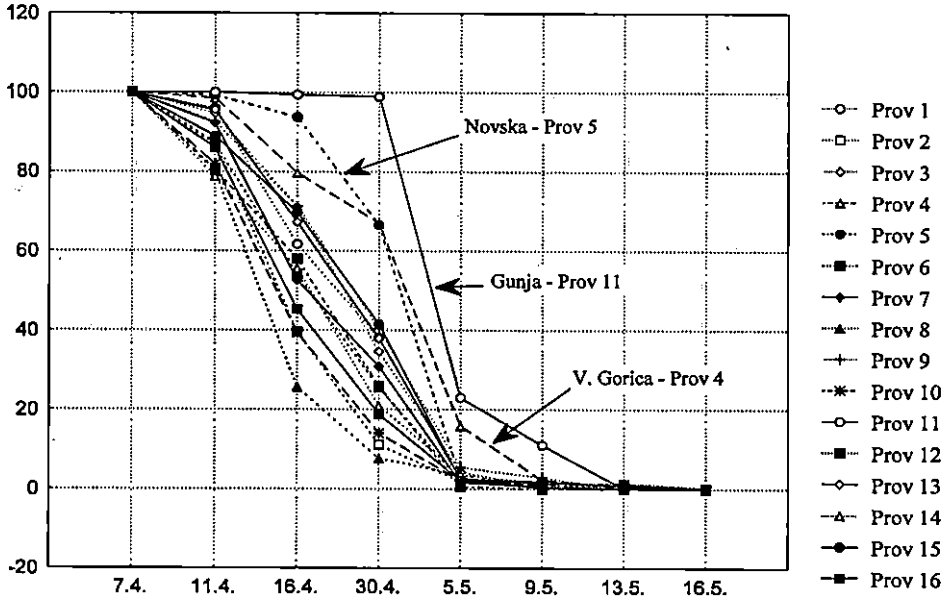

Figure 1. Percentage by provenances entering into phase 2 (1997)

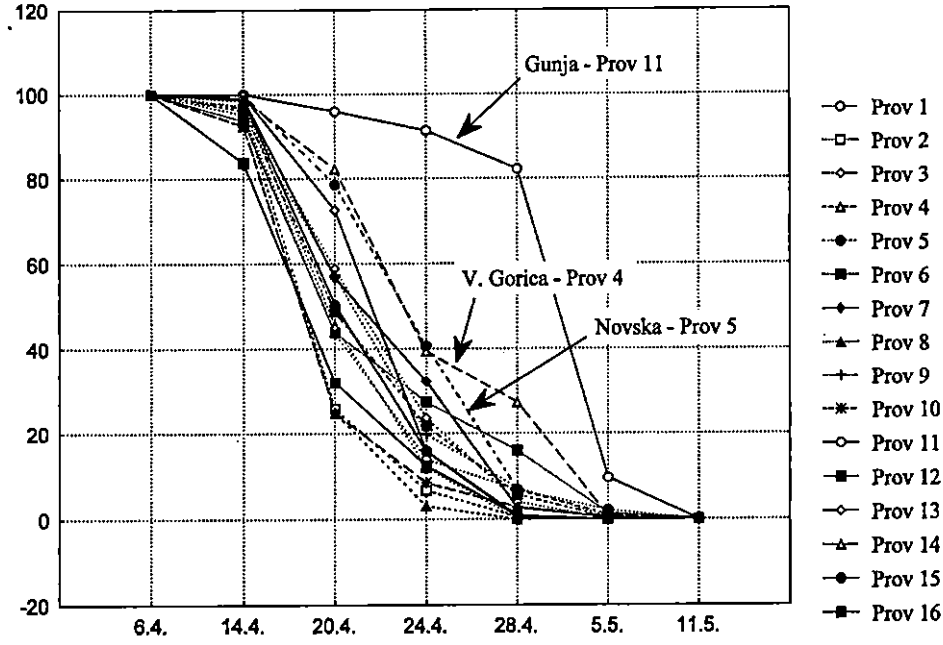

Figure 2. Percentage by provenances entering into phase 2 (1998)

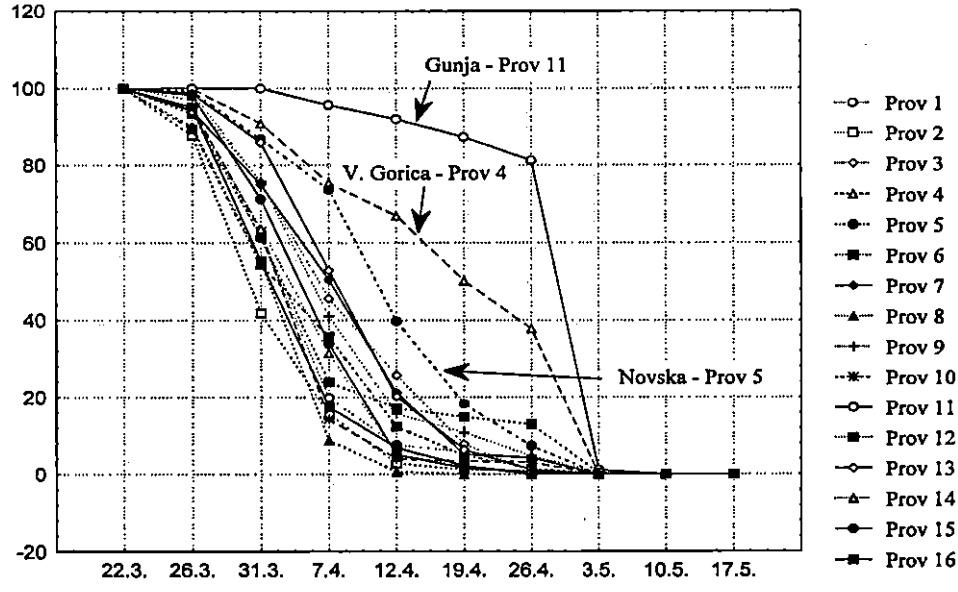

Figure 3. Percentage by provenances entering into phase 2 (1999)

tion indicates quantitative variability where the issue may be a larger number of genes which define a certain characteristic or this characteristic may be due to a lesser degree of heritability. The charts for Gunja and Đurđenovac provenances have abrupt, sharp transitions from phase 1 to phase 2 which indicate discontinued flushing variability for these provenances. The flushing is influenced by the smaller number of genes, i.e. the heritability feature is more prominent. According to the charts, the Velika Gorica and Novska provenances fall under the group of late flushing provenances, but they are a mixture of early and late genotypes where the late genotype prevails.

Figures 4, 5 and 6 show the tendencies in the transition from phase 6 to phase 7 for Pedunculate Oak provenances by year. The earliest start of the process of transition into phase 7 occurred after April 19 1999, and the latest only after May 9 1997. The Đurđevac and Spačva provenances have the earliest and shortest transition into phase 7. For this transition, they needed only 11 days in 1997, 17 days in 1998 and as many as 28 days in 1999. The latest transition into phase 7 was noted in the Gunja, Velika Gorica and Novska provenances. In early May until May 16 in 1997, May 15 in 1998 and May 10 in 1999, over 90% of the plants from these provenances were still in phase 6. After these dates a sharp transition into phase 7 began. The Gunja provenance has the steepest chart line and the most homogenous transition which confirms the discontinued flushing variability for this provenance. Figures 7, 8 and 9 show the percentage in flushing phases by provenance for May 5 1997, May 5 1998 and May 3 1999. A significantly narrower span of flushing phases in 1997 is noticed (1 to 5). This is directly connected to the air temperatures in March, April and May. Data shown in Table 2 on the mean maximum and minimum temperatures recorded at the meteorological station in Jastrebarsko confirm this. April 1997 had much lower air temperature values. The mean temperature was 7.2 °C, the maximum being 20.5 °C and the minimum –4.5°C. 1998 and 1999 had almost equal temperature values (mean value of 11.9°C and 11.1°C, a maximum monthly value of 25.6°C and 25°C and a minimum monthly value of –1.5°C and 0.6°C). The appearance of phases 1 to 7 on May 5 1998 and May 3 1999 shows quicker flushing dynamics in comparison with May 5 1997 where only 5 phases were recorded (1-5). The average intensity of the presence of the individual phases varies significantly through the monitored years. On May 5 1997 the dominant phase was phase 3, on May 5 1999 it was phase 5 and on May 3 1998 phase 6. The largest deviation from the average phase presence was noted in the Gunja, Velika Gorica, Spačva and Đurđenovac provenances. In the Gunja and Velika Gorica provenances, on May 5 1997 and May 5 1998 phase 2 was dominant, whereas on May 3 1999 the dominant phase was 3. In the Spačva and Đurđenovac provenances on May 5 1997 phase 4 was dominant and on May 5 1998 phase 6 was dominant, whereas on May 3 1999 the dominant phase was 7. Throughout the three year monitoring period with monitoring times being almost identical (May 5 1997, May 5 1998, May 3 1999), the Gunja and Velika Gorica provenances show clear late flushing characteristics, whereas the Spačva and

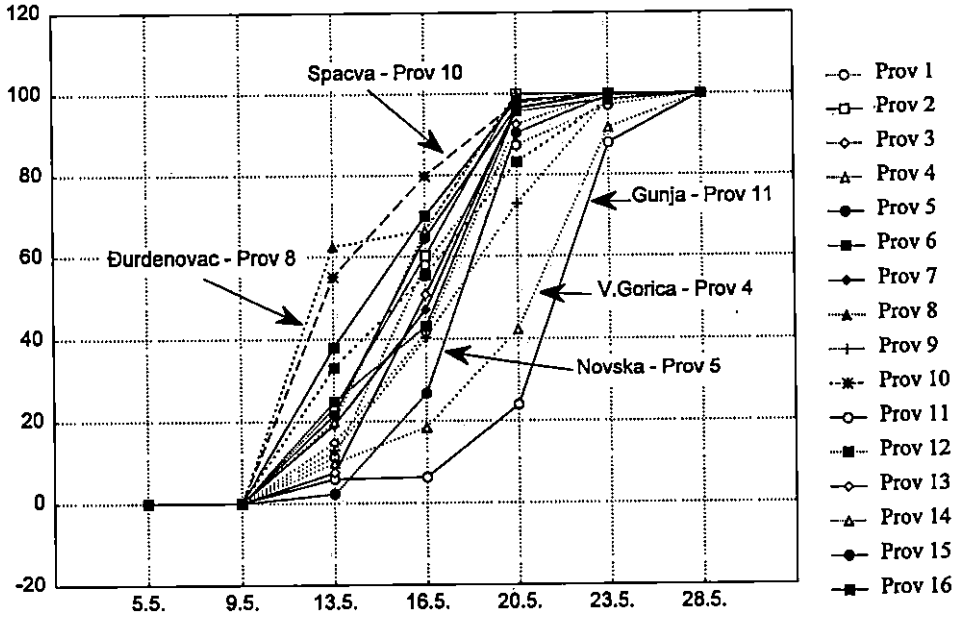

Figure 4. Percentage by provenances entering into phase 7 (1997)

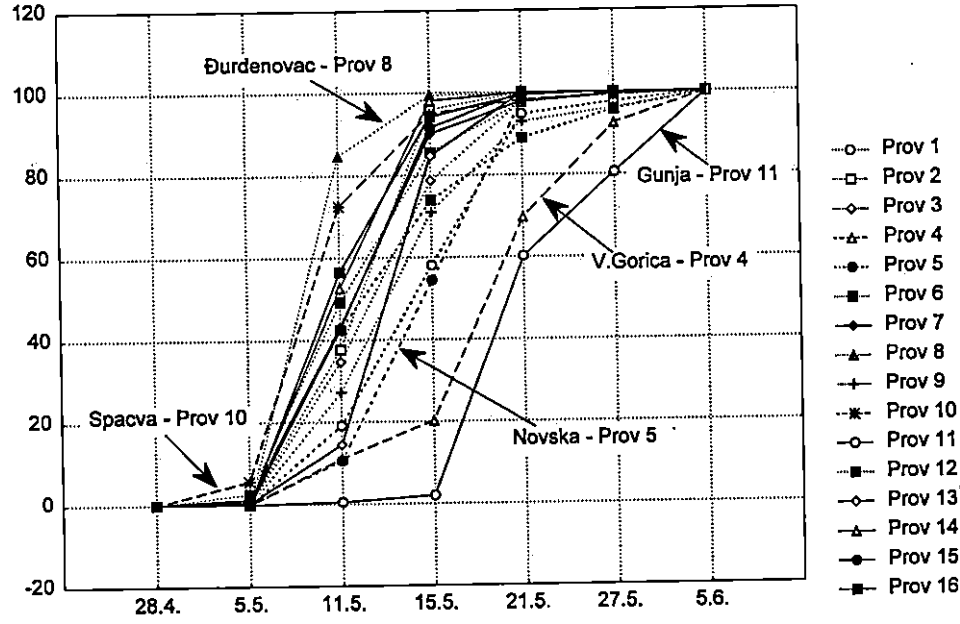

Figure 5. Percentage by provenances entering into phase 7 (1998)

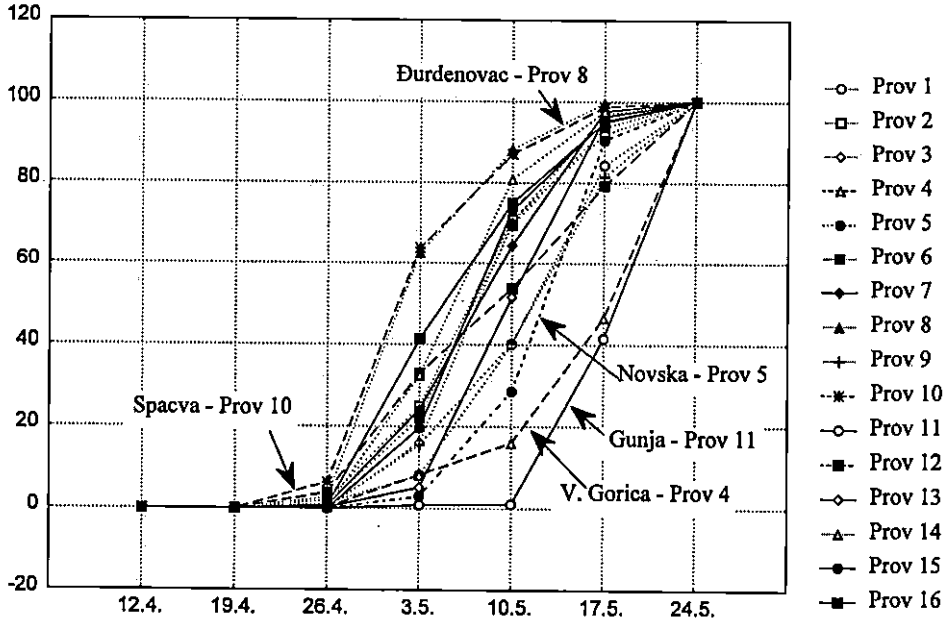

Figure 6. Percentage by provenances entering into phase 7 (1999)

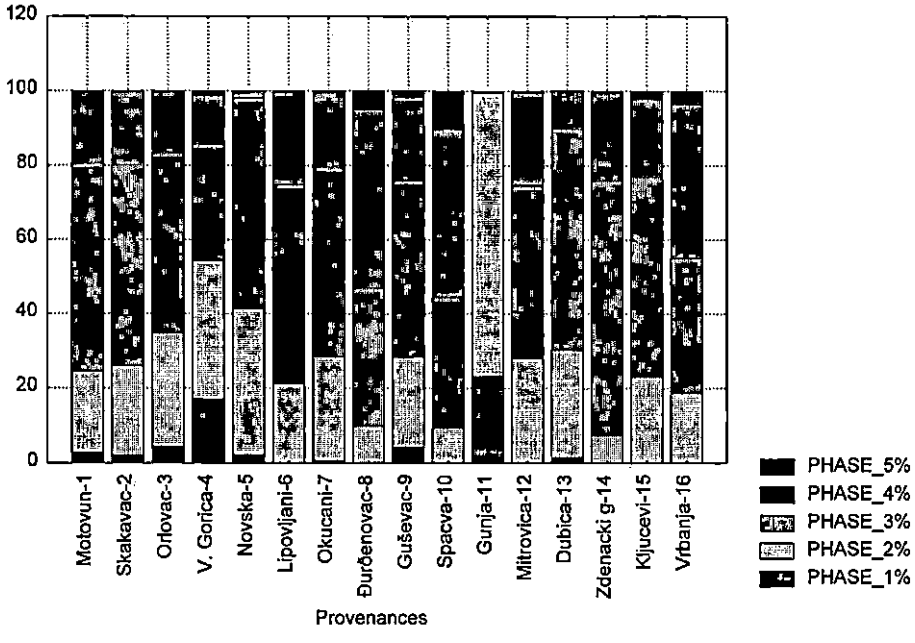

Figure 7. Number of plants in different flushing phases on May 5, 1997

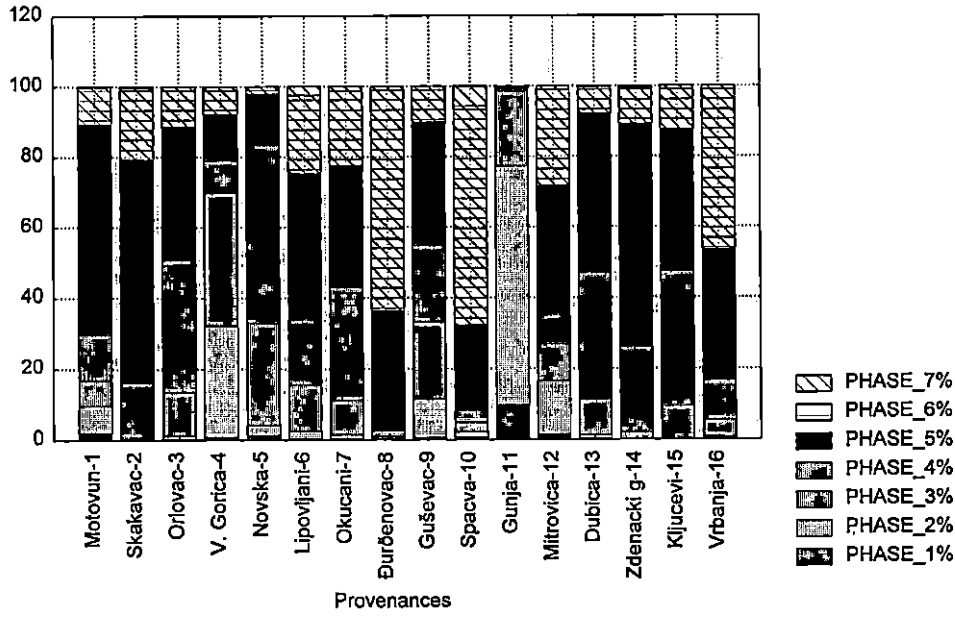

Figure 8. Number of plants in different flushing phases on May 5, 1998

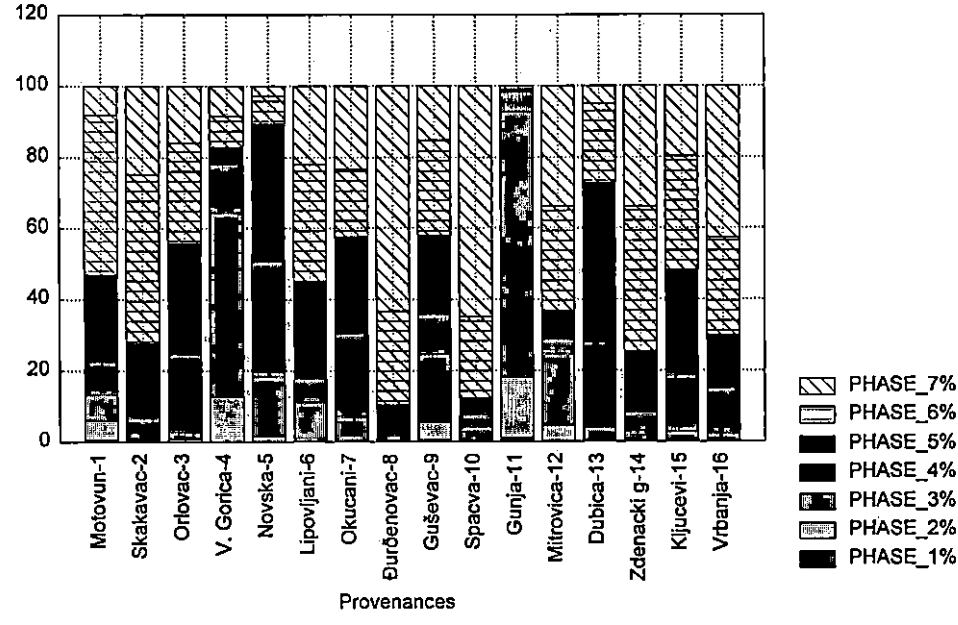

Figure 9. Number of plants in different flushing phases on May 3, 1999

Đurđenovac provenances show clear early flushing characteristics. These data prove a time difference in the flushing of early and late Pedunculate Oak. The temperatures during this three-year period influence the dynamics of flushing but the results indicate the existence of larger genetic variability which influences this characteristic.

The existence of early and late flushing in Pedunculate Oak is especially important for the Oak itself. Therefore, special forms of Oak have been given names: *tarda* Nordel, *tardissima* Sim and *tardiflora* Czern. for late flushers and *praecox* Czern for early flushers. Flushing is inherited polygenously, with three pairs of genes where the early form is semi-dominant (Stojković 1978, 1991). Research on the differences in the beginning of flushing in the provenance tests started early. According to Krahl-Urban (1959), there is a three-week difference in flushing between the late Slavonian provenance and the German provenance. Literature contains different information, stating that the differences range from 7 days (Hendrich 1973) to 2-4 weeks (Šafar 1966).

The research on the flushing variability in the Pedunculate Oak provenance test has defined the range of variability for 1997, 1998 and 1999 as well as the range of the variability of phases 1, 2 and 7. The range of flushing variability for 1997 equals 51 days, while for 1998 and 1999 it equals 60 days. If compared to the data given by Stojković (1991) which defines the range of variability at 54 days, we can notice a prolongment of 6 days for 1999.

Monitoring flushing by provenance and phases has provided an insight into the range of the variability of individual phases. The range of variability for phase 1 for the Đurđenovac and Skakavac provenance is 32 days, for the Gunja provenance 20 days and for the Moravić provenance as much as 32 days. The variability range for phase 2 ranges from 18 days for the Đurđenovac provenance to 34 days for the Velika Gorica and Guševac provenances. In phase 7 the shortest variability of 7 days is recorded for the Gunja provenance, while the range for the provenance Spačva is 22 days. By observing the very beginning of flushing in the Pedunculate Oak provenances we can notice a significant difference between Gunja and Velika Gorica provenances and the Spačva and Đurđenovac provenances. The provenances which transform in the shortest time and are earliest from phase 1 to phase 2, i.e. are the first to start the flushing process, show the same trend in the transition from phase 6 to phase 7.

Table 6 gives information on the average number of days in which 25%, 50% and 75% of the plants entered phase 2. The data for 1995 show an even transformation into phase 2. Information regarding the moment when 25% of the plants are in transition shows that this occurs on the 28th day for the Gunja provenance, on the 23rd day for the Velika Gorica and Novska provenances, and on the 9th day from the start of the monitoring (April 7, 1997) for all the other provenances. In the 75% transition into phase 2, two groups are distinguishable. The first is comprised of the Skakavac, Đurđenovac, Spačva, Zdenački Gaj and Vrbanja provenances where 75% of the plants enter phase 2 on the 23rd day. The second group is the

Table 6. The averge number of days for flushing entering into phase two

Provenances	The averge number of days for flushing change to phase two														
	7.4.1997.					6.4.1998.					22.3.1999.				
	25% plants	50% plants	75% plants	Mean	Standard error	25% plants	50% plants	75% plants	Mean	Standard error	25% plants	50% plants	75% plants	Mean	Standard error
1	9	23	28	19.47	0.48	14	14	18	16.62	0.26	9	16	16	15.41	0.43
2	9	9	23	14.63	0.46	14	14	18	15.11	0.16	9	9	16	12.40	0.34
3	9	23	28	20.62	0.44	14	18	18	17.42	0.21	16	16	28	18.97	0.42
4	23	28	28	24.18	0.44	18	18	29	20.77	0.31	21	28	42	29.87	0.62
5	23	28	28	25.61	0.28	18	18	22	19.33	0.22	18	21	28	23.34	0.46
6	9	23	28	17.45	0.50	14	14	18	17.05	0.23	9	16	21	15.38	0.45
7	9	23	28	17.63	0.50	14	18	22	17.72	0.22	9	21	21	18.53	0.46
8	9	9	23	12.19	0.44	14	14	16	14.67	0.15	9	16	16	12.89	0.27
9	9	23	28	20.94	0.47	14	18	18	17.33	0.25	16	16	21	18.40	0.46
10	9	9	23	14.49	0.48	14	14	14	15.10	0.21	9	16	16	14.64	0.37
11	28	28	28	29.23	0.17	29	29	29	27.83	0.25	42	42	42	49.14	0.37
12	9	23	28	17.30	0.50	14	14	22	17.66	0.33	9	16	16	17.36	0.60
13	9	23	28	20.26	0.47	14	18	18	17.58	0.15	16	21	21	19.60	0.38
14	9	23	23	17.03	0.53	14	14	18	16.19	0.16	9	16	21	15.20	0.35
15	9	23	28	20.37	0.51	14	18	18	16.60	0.18	9	16	21	16.36	0.34
16	9	9	23	15.75	0.50	14	14	18	14.86	0.23	9	16	16	14.09	0.34

Table 7. Test of Equality over Strata

Test	1997			1998			1999		
	Chi-Square	DF	Pr > Chi-Square	Chi-Square	DF	Pr > Chi-Square	Chi-Square	DF	Pr > Chi-Square
Log-Rank	1209.287	15	0.0001	1620.342	15	0.0001	2015.657	15	0.0001
Wilcoxon	1277.508	15	0.0001	1383.436	15	0.0001	1618.753	15	0.0001
-2Log (LR)	270.538	15	0.0001	139.650	15	0.0001	540.206	15	0.0001

Motovun, Orlovac, Velika Gorica, Novska, Lipovljani, Okučani, Guševac, Gunja, Morović, Dubica and Ključevi provenances where 75% of the plants enter phase 2 on the 28th day. From the data collected for 1998 it is visible that the Gunja provenance has 25% of plants in phase 2 on the 29th day, Velika Gorica and Novska on the 18th day and the other provenances on the 14th day from the first day of monitoring (April 4 1998). For a percentage of 75%, only plants from the Gunja and Velika Gorica provenances entered phase 2 on the 29th day, which once again confirms the late flushing of these provenances. Data for 1999 show that the Gunja and Velika Gorica provenances differ from the rest of the provenances. The Velika Gorica provenance has 25% of its plants in phase 2 on the 21st day from the beginning of monitoring, 50% on the 28th day and 75% on day 42. If we observe the transition of 15% of the plants into phase 2, we can see that the Motovun, Skakavac, Lipovljani, Okučani, Đurđenovac, Spačva, Morović, Zdenački Gaj, Ključevi and Vrbanja provenances act in the same way. Already on the 9th day from the beginning of monitoring 25% of all plants have entered phase 2, while this transition in the Gunja provenance occurs on the 42nd day. It is also interesting to note that the transition into phase 2 for 15% to 75% of the plants of the Gunja provenance happens on the 42nd day. This sharp transition can be seen in Chart 1 where we can see the steep fall of the line between April 24 and May 3. Between these two dates comes the 42nd day of monitoring. A large deviation of the mean value from the median represents an unequal transition from phase 1 to phase 2. An example of this is the Gunja and Đurđenovac provenances. The Đurđenovac provenance has a median significantly lower than the mean value which indicates a sharp transition into phase 2 in the first days of monitoring, while the Gunja provenance has a median significantly higher than the mean value and its plants remain in phase 1 longer and then rapidly enter into phase 2.

The differences in the time distribution for the beginning of phase 2 by provenance have been tested in parameterless tests shown in Table 9. These two tests (log-rank and Wilcoxon) indicate the differences in time distribution of the beginning of phase 2 by provenance. Both tests are equally significant ($p < .001$).

On the basis of the given facts we can categorise all the provenances into 3 groups. The first group consists of the provenances which enter phase 7 the soonest – the early flushing provenances of Đurđenovac and Spačva. The second group consists of those which enter phase 7 at a medium speed – the Motovun, Sklakavac, Orlovac, Lipovljani, Okučani, Guševac, Morović, Dubica, Zdenački Gaj,

Ključevi and Vrbanja provenances, and the third group consists of the provenances which enter phase 7 the latest – the late flushing provenances of Gunja, Velika Gorica and Novska.

CONCLUSIONS

On the basis of the results of this research on the growth success of Pedunculate Oak provenances and the flushing monitoring at the Gajno locality, we can conclude:

The highest survival percentage is found in the Orlovac (93%), Guševac (91%) and Lipovljani (90%) provenances and the lowest in the Ključevi (77.75%) provenance. The results of the diameter and height measurements indicate the best growth success in the Spačva, Đurđenovac, Okučani and Gunja provenances, while the worst is for provenance Motovun.

We can divide all provenances into three groups according to the speed and way of flushing. The first consists of the early flushing provenances (Đurđenovac and Spačva), the second of the medium flushing provenances (Motovun, Skakavac, Orlovac, Lipovljani, Okučani, Guševac, Morović, Dubica, Zdenački Gaj, Ključevi and Vrbanja) and the third group of the late flushing provenances (Gunja, Velika Gorica and Novska). The Novska provenance falls under the group of late flushing provenances with a mixture of early and late genotypes where the late genotype prevails.

Monitoring of the Pedunculate Oak flushing in 7 phases during 1997, 1998 and 1999 indicates a trend of flushing in each of the 16 provenances and the existence of high variability regardless of the identical beginning and conclusion of flushing. In the three year research with an almost identical time of monitoring (May 5, 1997; May 5 1998; May 3 1999), the Gunja and Velika Gorica provenances show distinctive late flushing characteristics and the Spačva and Đurđenovac provenances distinctive early flushing characteristics. This information indicates a shift in flushing time between the early and late Pedunculate Oak. The average number of days when 75% of the plants enter into flushing phase 2 for the Gunja provenance is 28 in 1997, 29 in 1998 and 42 in 1999. For the Đurđenovac provenance it equals 23 days in 1997, 14 in 1998 and 16 in 1999.

The scale of flushing variability for 1997 is 51 days and for 1998 and 1999 it is 60 days. The scale of phase 1 variability in 1999 for the Đurđenovac and Skakavac provenances is only 13 days, for the Gunja provenance 20 days and for the Morović provenance as high as 32 days. The scale of phase 2 variability is from 18 days for the Đurđenovac provenance to 32 days for the Velika Gorica and Guševac provenances. In phase 7 the Gunja provenance has the lowest variability scale of only 7 days while the Spačva provenance has a variability scale of 22 days. The parameterless tests (Log-rank and Wilcoxon) indicate differences in the time distribution of the beginning of phase 2 by provenance for years 1997, 1998 and 1999. Both tests are highly significant.

The temperature during the monitored years influences the flushing dynamics, but the results indicate the existence of higher genetic variability for this characteristic.

The results of this research indicate the existence of three types of Pedunculate Oak flushing in Croatia. Because of the importance of this research we recommend that it be continued.

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VARIJABILNOST LISTANJA HRASTA LUŽNJAKA (*QUERCUS ROBUR* L.) U POKUSU PROVENIJENCIJA U POKUPLJU

Pokus provenijencija hrasta lužnjaka, s ukupno 16 provenijencija, osnovan je u proljeće 1988. godine na lokalitetu Gajno, u Pokuplju. Pokus je osnovan kao randomizirani blok-sustav u četiri ponavljanja s ukupno 400 dvogodišnjih sadnica po provenijenciji. Izučavanje početka listanja hrasta lužnjaka (*Quercus robur* L.) po provenijencijama i ponavljanjima počelo je u proljeće 1992. godine i nastavilo se tijekom 1993. i 1994. godine. Uočene su znatne razlike u širini varijabilnosti ovoga svojstva. Širina varijabilnosti listanja tijekom 1992. godine iznosila je tri tjedna, 1993. četiri tjedna, a 1994. šest tjedana. Detaljnije izučavanje svojstva listanja hrasta lužnjaka počelo je 1997. godine, a provodi se u sedam faza. Rezultati ovih istraživanja upućuju na varijabilnost listanja po provenijencijama i ponavljanjima za svaku od sedam promatranih faza.

Ključne riječi: provenijencije hrasta lužnjaka, varijabilnost faza listanja, Hrvatska