Evaluation of twenty-years-old pedunculate and sessile oak provenance trial

V. Buriánek[1], M. Benedíková[2], J. Kyseláková[2]

[1]*Forestry and Game Management Research Institute, Strnady, Jíloviště, Czech Republic*
[2]*Forestry and Game Management Research Institute, Strnady, Kunovice Research Station, Kunovice, Czech Republic*

ABSTRACT: This paper deals with the measurement and evaluation of pedunculate and sessile oaks on five provenance trial plots located in the forest regions Západočeská pahorkatina, Jihočeská pánev, Hornomoravský úval, Dolnomoravský úval, Bílé Karpaty and Vizovické vrchy at the age of 20 years. Height and diameter growth were measured and analysed and the quality of tree stems was recorded. Sampled seeds originated from certified stands for seed production located in the Hercynian and Carpathian regions of the Czech Republic. Differences between the two species result from their ecological requirements. A comparison of the two species indicates that pedunculate oak at young age grows better than sessile oak in its typical site conditions. Sessile oak grows relatively worse on the plots situated in floodplain site conditions because it does not tolerate the high levels of groundwater. But the differences were not statistically significant. Significant differences in growth parameters were confirmed within each species among plots and provenances. Large differences in stem shape quality were also recorded already in the early growth phase. In some provenances straight stems were present in up to 56% of the individuals, however, in others straight stems did not appear at all. The total results showed that some pedunculate and sessile oak provenances are more adaptable to site conditions and they suffer lower losses while achieving very good growth.

Keywords: Czech Republic; evaluation; pedunculate oak; provenance research; sessile oak; variability in height and diameter growth

The potential natural proportion of oaks in the forest tree species composition in the Czech Republic is estimated to be 19.3% (Plíva, Žlábek 1986). Currently, the proportion of oak species accounts only for 6.8% of forest land area (Report on the State of Forest and Forestry in the Czech Republic, 2008), however, the recommended oak proportion in present and future forests is 9%. Two main oak species are naturally distributed in the Czech Republic: pedunculate oak – *Quercus robur* L. and sessile oak – *Quercus petraea* (Matt.) Liebl. Oak stands cover a large area in the lower forest vegetation zones (oak, oak-beech and beech-oak), mostly at altitudes up to 550 m a.s.l. Large stands occur mainly in the natural forest regions Polabí, Moravské úvaly, Slezská nížina, Podkrušnohorské pánve, Středomoravské Karpaty, České středohoří and Křivoklátsko.

Silvicultural and management systems, lack of natural regeneration, often damaged by game, and partly oak dieback caused by pathogens were the main factors affecting decline of oaks in the tree species composition. Oaks in broadleaved forests are also endangered by other tree species in mixture due to hard competition (Prudič 1992). Losses of oaks are different in each type of forest vegetation zone.

The main goal of the present research is to analyse the growth performance of oak provenances twenty years after outplanting. The paper is focused on a comparison of pedunculate and sessile oak progenies. Another goal was the investigation of genetically conditioned traits and the variabil-

Supported by the Ministry of Agriculture of the Czech Republic, Project No. 0002070203.

ity of these oak species on provenance plots established using identical methods in forest regions with significant occurrence of oak, under different ecological conditions. Simultaneously, exact data on the growth of oak populations in defined conditions on research plots are provided.

MATERIALS AND METHODS

Ten oak provenance plots were gradually established in the years 1984–1986. The seed (acorns) was harvested in certified seed stands in the rich seed year 1982. The progenies of 45 provenances from various regions and site conditions within the Czech Republic were used for the establishment of the first set of five oak provenance research plots aimed to test and verify individual provenances in 1984. The plots were established in regions where significant proportions of oaks occurred in the forests. All the plots were measured and evaluated at the age of 8 years and consequently at the age of 10 and 15 years (Benedíková 2000, 2003).

Fifty plants of each test provenance were planted onto the rectangular area 10 × 10 m in 4 replications using the plant spacing 1.4 × 0.7 m. After 20 years, the growth of provenances was evaluated on one half of these plots. The second half had to be eliminated during the first years after their outplanting due to high plant mortality resulting from game damage, late frosts, fire etc. The list of oak provenances originating from 16 forest regions is given in Table 1, the characteristics of provenance plots are described in Table 2, and basic climatic data are shown in Table 3.

Data collected for each tree included height growth, dbh, type of branching, stem shape, tree health and flushing process using the following parameters:

– Type of branching was ranked using the scale: 1 – straight stem (bole), 2 – branched crown (crown in the upper third of the stem), 3 – bifurcated crown, 4 – crown bifurcation in the second third of the stem, and 5 – crown or bifurcation in the first third of the stem.
– Stem shape: 1 – straight, 2 – slightly curved, 3 – crooked, 4 – twisted (multiple crooks).
– Health condition: 1 – healthy, 2 – slightly damaged, 3 – strongly damaged.
– Flushing process: 0 – very late bud flush (winter, dormant bud), 1 – late bud flush (elongated bud), 2 – middle bud flush (flushing leaf), 3 – early bud flush (young leaf), and 4 – very early bud flush (fully developed leaf).

Measurement of tree growth, branching, stem shape and health evaluation were carried out in spring 2004 while phenological observations on all plots were accomplished during one week in spring 2002.

The influence of the replication, provenance and localities on growth and stem shape of each provenance was tested on all plots. The results were evaluated and tested statistically and compared with the results of previous surveys. Before statistical evaluation the normality of distribution within the compared groups was assessed using the Kolmogorov-Smirnov test (KS test). To determine the significance of differences among individual provenances the model of statistical test analysis of variance (ANOVA) on the data transformed by natural logarithm was performed (Table 4), followed by subsequent Duncan's ordinal multiple test.

The data analysis during statistical processing was done separately for continuous parameters – height and breast-height diameter, and discontinuous parameters (categorized variables) – type of branching, stem shape and health condition. $P < 0.05$ values were considered as statistically significant (i. e. they indicate differences among compared groups).

The following factors (source of variance) were used for the evaluation of continuous parameters:

(1) Differences among provenances in height and dbh parameters without differentiation of replications separately for the two species (pedunculate and sessile oak). The values of basic characteristics of individual provenances were determined for: the mean, number of values, standard deviation, median, coefficient of variance, minimum and maximum.
(2) Differences among replications 1–4 within provenances in parameters of height and dbh. $P < 0.05$ were considered as non-significant (i.e. the difference between appropriate combinations of replications within a given provenance).
(3) Differences among plots based on tree height and dbh of provenances grown on more plots were evaluated separately with using Dunnett's *a posteriori* test ($P < 0.05$) – Table 5.

Evaluation of qualitative characteristics – type of branching, stem shape and health condition – mode (i.e. the most frequent class), number of observations in mode class (N – mode), total number of individuals of the given provenance (N – sum), relative (%) number of observations in mode class (% – mode) and weighted mean of evaluated categories were computed besides the frequencies in each class. Typological classification of provenance origin and research plots was described according to Plíva (1991).

Table 1. List of tested oak provenances

Provenance No.	Oak species	Provenance origin	Forest type	Altitude m a.s.l.
1	*Q. robur*	Strážnice – Kunovice	1L0 – elm floodplain forest	177
2	*Q. petraea*	Bučovice – Luleč	3S7 – fresh oak-beech forest	415
3	*Q. robur*	Litovel – Březová	1L2 – elm floodplain forest	227
4	*Q. robur*	Mladá Boleslav – Březno	1H – loess hornbeam-oak forest	315
5	*Q. robur*	Jindř. Hradec – Kard. Řečice	3B2 – rich oak-beech forest	440
6	*Q. robur*	Písek – Písek	2L1 – stream floodplain forest	480
7	*Q. robur*	Vys. Chvojno – N. Hradec	2O5 – fir-(beech)-oak forest	260
8	*Q. petraea*	Stříbro – Obora	3H – loamy oak-beech forest	440
9	*Q. robur*	Zbiroh – Opyš	3I1 – compresse acid oak-beech forest	450
10	*Q. petraea*	Buchlovice – Velehrad	3H2 – loamy oak-beech forest	400
11	*Q. petraea*	Křivoklát – Kouřimec	2K3 – acid beech-oak forest	460
12	*Q. robur*	Křivoklát – Kolna	3H3 – loamy oak-beech forest	400
13	*Q. robur*	Litovel – Troubky	1L2 – elm floodplain forest	199
14	*Q. robur*	Litovel – Střeň	1P1 – fresh birch-oak forest	233
15	*Q. robur*	Litovel – Troubky	1L2 – elm floodplain forest	199
16	*Q. robur*	Mělník – Tuháň	1L2 – elm floodplain forest	150
17	*Q. robur*	Chlumec – Hlušice	1B2 – rich hornbeam-oak forest	240
18	*Q. robur*	Opočno – Mochov	1D3 – enriched hornbeam-oak forest	250
19	*Q. petraea*	Plasy – Čečiny	3I1– compresse acid oak-beech forest	430
20	*Q. petraea*	Plasy – Doubrava	2Q – poor fir-oak forest	400
21	*Q. robur*	Šenov – Proskovice	1L2 – elm floodplain forest	215
22	*Q. robur*	Židlochovice – Tvrdonice	1L9 – elm floodplain forest	155
24	*Q. robur*	Nymburk – Dymokury	1O7 – lime-oak forest	220
25	*Q. robur*	Strážnice – Hodonín	1S8 – (hornbeam)-oak forest on sands	169
26	*Q. robur*	Strážnice – Hodonín	1S3 – (hornbeam)-oak forest on sands	167
27	*Q. robur*	Mělník – Košátky	1L2 – elm floodplain forest	165
28	*Q. robur*	Hořice – Smolník	1V4 – humid hornbeam-oak forest	270
29	*Q. petraea*	Znojmo – Čížov	2K9 – acid beech-oak forest	400
30	*Q. petraea*	Kuřim – Moravské Knínice	2S4 – fresh beech-oak forest	380
31	*Q. petraea*	Bučovice – Lovčice	2O5 – fir-(beech)-oak forest	350
32	*Q. robur*	Ronov – Choltice (Žehušice)	1L2 – elm floodplain forest	280
33	*Q. petraea*	Luhačovice – Uherský Brod	2H3 – loamy (loess) hornbeam-oak f.	320
34	*Q. petraea*	Frenštát p. R. – Jindřichov	2H – loamy (loess) hornbeam-oak f.	320
35	*Q. petraea*	Jaroměřice n. R. – Rozkoš	2H5 – loamy (loess) hornbeam-oak f.	420
36	*Q. robur*	Opava – Chuchelná	2H1 – loamy (loess) hornbeam-oak f.	240
37	*Q. petraea*	Jaroměřice n. R.– Hrotovice	2H2 – loamy (loess) hornbeam-oak f.	420
38	*Q. robur*	Kašp. Hory – Horažďovice	2S2 – fresh beech-oak forest	430
39	*Q. petraea*	ŠLP Kostelec n. Č. lesy	3K6 – acid oak-beech forest	280
40	*Q. robur*	Vysoké Chvojno – Jelení	1P4 – fresh birch-oak forest	260
41	*Q. petraea*	Buchlovice – Koryčany	3H2 – loamy oak-beech forest	350
42	*Q. petraea*	SPLO Jíloviště – Třebotov	2C1– drying beech-oak forest	350
43	*Q. robur*	Nové Hrady – Jakule	4O1 – fresh oak-fir forest	480
44	*Q. robur*	Česká Lípa – Žandov	2L – stream floodplain forest	270
45	*Q. robur*	Strážnice – Hodonín	1S3 – (hornbeam)-oak forest on sands	172
46	*Q. robur*	Litoměřice – Roudnice	1G4 – waterlogged willow-alder f.	180

Table 2. The characteristics of provenance plots

Provenance plot	Number of provenances		Natural forest zone	Altitude m a.s.l.	Forest type
	Q. robur	*Q. petraea*			
Malenovice	24	16	38	310	3H2 – loamy (loess) hornbeam-oak
Netolice	22	14	15	410	3O5 – fir-oak-beech
Plasy	21	14	6	430	2K3 – acid beech-oak
Troubky	28	14	34	200	1L2 – elm floodplain
Tvrdonice	23	13	35	155	1L9 – elm floodplain

RESULTS

The results of analysis of variance for tree heights and dbh are presented in Table 4. Summary statistics of source data (tree heights and dbh values) at all sites are given in Tables 6 and 7. The resulting data on mean heights for individual provenances at the age of 15 and 20 years were compared (separately for pedunculate and sessile oak) – Figs. 1–5. A comparison of mean heights

Table 3. Supposed annual mean temperature and precipitation amount on oak provenance plots in 1984 – 2007 taken from the nearest meteorological stations. The missing data at Husinec station were caused by extreme flooding in 2002

Year	Provenance plot (meteorological station)									
	Malenovice (Holešov)		Netolice (Husinec)		Plasy (Kralovice)		Troubky (Přerov)		Tvrdonice (Lednice)	
	°C	mm	°C	mm	°C	mm	°C	mm	°C	mm
1984	8.4	600.2	7.2	589.9	7.2	487.8	8.3	596.0	8.9	484.6
1985	7.3	722.4	6.8	733.3	6.8	459.0	7.1	748.4	8.0	687.8
1986	8.1	532.0	6.8	548.5	7.5	480.8	8.1	516.8	8.9	428.2
1987	7.7	773.7	6.6	710.6	6.9	502.8	7.8	682.8	8.6	577.7
1988	9.0	550.6	8.1	778.9	8.2	453.1	9.1	534.0	9.7	442.8
1989	9.4	530.1	8.4	600.6	8.6	457.4	9.4	473.4	9.9	387.1
1990	9.3	606.7	8.3	591.6	8.8	415.5	9.3	675.3	10.0	443.4
1991	8.3	618.0	7.1	564.1	7.8	334.8	8.1	525.8	9.0	390.0
1992	9.7	526.5	8.7	595.1	8.9	450.1	9.6	499.9	10.4	431.0
1993	8.7	494.5	7.7	728.3	8.2	481.9	8.5	426.2	9.4	488.1
1994	10.1	670.6	9.0	621.9	9.4	421.3	9.8	628.7	10.9	457.9
1995	9.1	760.8	7.7	822.3	8.3	592.3	8.9	605.3	10.0	570.0
1996	7.5	650.7	5.8	875.2	6.8	534.4	7.3	625.7	8.5	519.1
1997	8.5	809.3	7.1	672.0	8.2	393.4	8.3	697.1	9.5	635.5
1998	9.2	659.5	7.9	522.5	8.7	487.8	9.1	603.3	10.3	528.0
1999	9.7	634.1	7.9	600.0	8.8	475.5	9.5	522.0	10.4	482.4
2000	10.0	664.5	8.6	618.6	9.1	512.3	10.2	581.2	11.3	571.4
2001	8.8	815.4	7.5	626.1	8.1	573.7	8.7	695.5	9.8	620.1
2002	9.8	569.7	–	–	8.7	699.9	9.7	567.1	10.5	693.3
2003	9.5	447.4	–	465.8	8.6	304.4	9.2	481.9	10.3	393.8
2004	9.1	539.5	7.4	613.7	8.1	529.8	8.9	483.1	9.8	534.1
2005	8.8	696.9	7.1	874.3	8.1	410.2	8.6	532.1	9.5	567.5
2006	9.4	659.7	7.6	780.5	8.6	412.3	9.0	591.1	10.0	591.3
2007	10.2	758.1	8.6	663.9	9.3	435.5	10.3	549.6	11.2	595.1
Mean	9.0	637.1	7.7	679.6	8.2	471.1	8.9	576.8	9.8	521.7

Table 4. Analyse of variance (ANOVA) results of individual provenances on research plots for tree height/dbh

Interraction	MaxNe	MaxPl	MaxTr	Ma xTv	NexPl	NexTr	NexTv	PlxTr	PlxTv	TrxTv
1	−/++	++/++	++/++	++/−	++/++	++/++	++/++	++/++	++/++	+/+
2	−/−	++/++	++/++	+/−	++/++	++/++	−/−	++/++	++/++	++/++
3	−/++	++/++	++/++	++/−	++/++	++/++	++/++	++/++	++/++	++/++
4	+/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++
5							++/++			
6	−/++	++/++	++/++	++/+	++/++	++/++	++/++	++/++	++/++	++/++
7	−/+	++/++	++/++	++/+	++/++	++/++	++/++	++/++	++/++	++/++
8	−/−	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/+
9	++/++	++/++	++/++	++/+	++/++	++/++	++/++	++/++	++/++	++/++
10	++/++	++/++	++/++	++/−	++/++	++/++	++/++	++/++	++/++	++/++
11	++/++	++/++	++/++	++/−	++/++	++/++	++/++	++/++	++/++	++/++
12	−/+	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++
13					++/++	++/++	++/++	++/++	++/++	++/++
14			++/++							
15			++/++	++/++						
16	+/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/+
17		++/++	++/++	++/+				++/++	++/++	++/+
18		++/++	++/++	++/−				++/++	++/++	++/++
19			++/++	++/++						++/++
20	−/−	++/++	++/++	++/−	++/++	++/++	−/−	++/++	++/++	++/++
21					++/++	++/++		++/++		
22	−/−	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++
24	++/++	++/++	++/++	++/+	++/++	++/++	++/++	++/++	++/++	++/+
25	++/++		++/++	+/−		++/++	++/++			++/++
26		++/++	++/++	++/+				++/++	++/++	++/++
27	+/−	++/++	++/++		++/++	++/++		++/++		
28			++/++	++/++						++/++
29	−/−	++/++	++/++	++/−	++/++	++/++	+/−	++/++	++/++	++/++
30	++/++	++/++	++/++	++/−	++/++	++/++	++/++	++/++	++/++	++/+
31	−/++	++/++	++/++		++/++	++/++		++/++		
32	++/++	++/++	++/++	++/+	++/++	++/++	++/++	++/++	++/++	++/++
33	−/−	++/++	++/+	++/−	++/++	++/+	−/−	++/++	++/++	+/++
34	−/−	++/++	++/++	++/−	++/++	++/++	++/−	++/++	++/++	++/++
35	−/−	++/++	++/++	++/−	++/++	++/++	−/−	++/++	++/++	++/++
36	+/++	++/++	++/++	−/−	++/++	++/−	++/++	++/++	++/++	++/++
38	−/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++
39	++/+	++/++	++/++	+/++	++/++	++/++	++/++	++/++	++/++	++/++
40						++/++				
41	−/−	++/++			++/++					
42	++/++	++/++	++/++	−/−	++/++	++/++	++/++	++/++	++/++	++/++
43					++/++					
44			++/++	++/++						++/++
45	++/−	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++	++/++
46	++/−		++/++	++/++		++/++	++/++			++/++

++ significant difference at 0,01 significance level, + significant difference at 0,05 significance level, – non significant difference, Ma – Malenovice, Ne – Netolice, Pl – Plasy, Tr – Troubky, Tv – Tvrdonice

Table 5. Evaluation of differences in the provenance growth among plots

Provenance No.	Height (m)	dbh (cm)	Provenance	Height (m)	dbh (cm)
	Quercus robur		36	Tr>Ma,Tv,Ne>Pl	Tr>Tv,Ma>Ne>Pl
1	Tr>Tv,Ma>Ne>Pl	Tr>Tv>Ma,Ne>Pl	38	Tr>Tv>Ma>Ne>Pl	Tr>Tv>Ma,Ne>Pl
3	Tr>Tv,Ma>Ne>Pl	Tr>Tv>Ma,Ne>Pl	40	Tr>Ne	Tr>Ne
4	Tr>Tv>Ma>Ne>Pl	Tr>Tv>Ne>Ma>Pl	43	Ne>Pl	Ne>Pl
5	Tr>Ne	Tr>Ne	44	Tr>Tv>Ma	Tr>Tv>Ma
6	Tr>Ma,Tv>Pl,Ne	Tr>Tv>Ne,Ma>Pl	45	Tr>Tv>Ne,Ma>Pl	Tr>Tv>Ne>Ma>Pl
7	Tr>Tv>Ma>Ne>Pl	Tr>Tv>Ne,Ma>Pl	46	Tr>Tv>Ma,Ne	Tr>Tv>Ne>Ma
9	Tr>Tv>Ma,Ne>Pl	Tr>Tv>Ne>Ma>Pl		*Quercus petraea*	
12	Tr>Tv>Ma>Ne>Pl	Tr>Tv>Ne,Ma>Pl	2	Tr>Ma,Tv,Ne>Pl	Tr>Tv,Ne,Ma>Pl
13	Tr>Tv>Ne>Pl	Tr>Tv>Ne>Pl	8	Tr,Tv>Ma,Ne>Pl	Tr>Tv>Ne,Ma>Pl
14	Tr>Ne	Tr>Ne	10	Tr>Ma,Tv>Ne>Pl	Tr>Tv>Ma>Ne>Pl
15	Tr,Tv>Ma	Tr,Tv>Ma	11	Tr>Tv,Ma>Ne>Pl	Tr>Tv>Ma>Ne>Pl
16	Tr>Tv>Ma>Ne>Pl	Tr>Tv>Ma>Ne>Pl	19	Tr>Tv>Ma	Tr>Tv>Ma
17	Tr>Tv>Ma>Pl	Tr>Tv>Ma>Pl	20	Tr>Ma,Tv,Ne>Pl	Tr>Tv,Ne,Ma>Pl
18	Tr>Tv,Ma>Pl	Tr>Tv>Ma>Pl	29	Tr>Tv,Ne,Ma>Pl	Tr>Tv>Ne,Ma>Pl
21	Tr>Ne>Pl	Tr>Ne>Pl	30	Tr>Tv,Ma>Ne>Pl	Tr>Tv>Ma>Ne>Pl
22	Tr>Tv>Ma,Ne>Pl	Tr>Tv>Ne,Ma>Pl	31	Tr>Ma>Ne>Pl	Tr>Ma,Ne>Pl
24	Tr>Tv>Ma>Ne>Pl	Tr>Tv,Ma>Ne>Pl	33	Tr>Ma,Tv>Pl>Ne	Tr>Tv>Ma>Pl>Ne
25	Tr>Tv,Ma>Ne	Tr>Tv>Ma>Ne	34	Tr>Tv,Ma,Ne>Pl	Tr>Tv>Ne,Ma>Pl
26	Tr>Tv>Ma>Pl	Tr>Tv>Ma>Pl	35	Tr>Tv,Ne,Ma>Pl	Tr>Tv,Ne,Ma>Pl
27	Tr>Ne,Ma>Pl	Tr>Ne>Ma>Pl	39	Tr>Tv,Ma>Ne>Pl	Tr>Tv>Ne,Ma>Pl
28	Tr>Tv>Ma	Tr>Tv>Ma	41	Ma,Ne>Pl	Ne,Ma>Pl
32	Tr>Tv>Ma>Ne>Pl	Tr>Tv>Ma>Ne>Pl	42	Tr>Ma,Tv>Ne>Pl	Tr>Tv,Ma>Ne>Pl

Ma – Malenovice, Ne – Netolice, Pl – Plasy, Tr – Troubky, Tv – Tvrdonice

of individual provenances planted on all plots is shown in Fig. 6.

The mean values of height and breast-height diameter, separately for pedunculate and sessile oak, and total mean values for individual provenance plots are given in Tables 8 and 9.

The comparison of total mean heights of both oak species showed that pedunculate oak grows faster than sessile oak with the exception of Plasy plot, which is characterized by acid and drier site conditions (annual mean precipitation amount 471 mm only) more favourable for sessile oak. Sessile oak achieved larger breast-height diameter only on the plots Plasy and Netolice. It grows worse on the plots Troubky and Tvrdonice situated in floodplain areas. A more significant difference between the two species was recorded in breast-height diameter.

For the simplification of their interpretation the results of phenological observations were graphically visualized using calculated weighted means of the point evaluation. The evaluation of branching type, stem shape and health condition is not presented due to a large extent. They are briefly summarized in the following characteristics of individual provenance plots.

Malenovice provenance plot

The results of testing differences in height and breast-height diameter among particular replications document a number of significant partial differences observed in tree heights which did not have a systematic character. Smaller differences were determined in breast-height diameter.

Based on the comparison of mean height values a group of the best growing provenances has been chosen; four provenances of pedunculate oak: 25 Strážnice (mean height 9.26 m), 24 Mělník

(6.23 m), 3 Litovel (8.98 m), 18 Opočno (8.85 m) and one provenance of sessile oak: 42 Jíloviště (8.90 m). Within this group the provenances do not differ statistically significantly.

The group of the slowest growing provenances consists of two pedunculate oak provenances: 14 Litovel (4.96 m) and Strážnice (5.35 m), which differ significantly from the others.

The evaluation of the type of branching shows that almost all the oak provenances have the most common value (mode value) 2 – branching in the crown, when only sessile oak provenance 34 Frenštát had mode 1 – continuous stem. While comparing the stem shape, the most common value was 2 (gently curved) – found out in 26 provenances, then mode 1 (quite straight) – in 7 provenances, which is more common for sessile oak. Value 3 (crooked stem) was attributed only to provenance 42 Jaroměřice in the case of sessile oak, while in pedunculate oak it was observed in 6 provenances. The above-mentioned results show that sessile oak has straighter stem than pedunculate oak in the Malenovice area. In the evaluation of health condition, mode 2 (slightly damaged) appeared only in pedunculate oak provenance 27 Mělník and in sessile oak provenance 19 Plasy. All the other provenances had mode 1 (healthy).

Netolice provenance plot

On this plot the provenance of pedunculate oak 3 Litovel appears as the best growing (mean height 8.87 m), followed by sessile oak provenance 20 Plasy (8.70 m) and other pedunculate oak provenances: 46 Litoměřice (8.42 m), 4 Ml. Boleslav (8.41 m), 9 Zbiroh (8.31 m) and 3 Jindř. Hradec (8.27 m). The slowest growing provenances were these provenances of sessile oak: 11 Křivoklát (6.36 m) and 31 Bučovice (6.62 m) and of pedunculate oak: 12 Křivoklát (6.72 m) and 45 Strážnice (6.76 m).

The type of branching of sessile oak is characterized by the mode value 2 (crown in the upper third of the stem) in most cases, for pedunculate oak mode 3

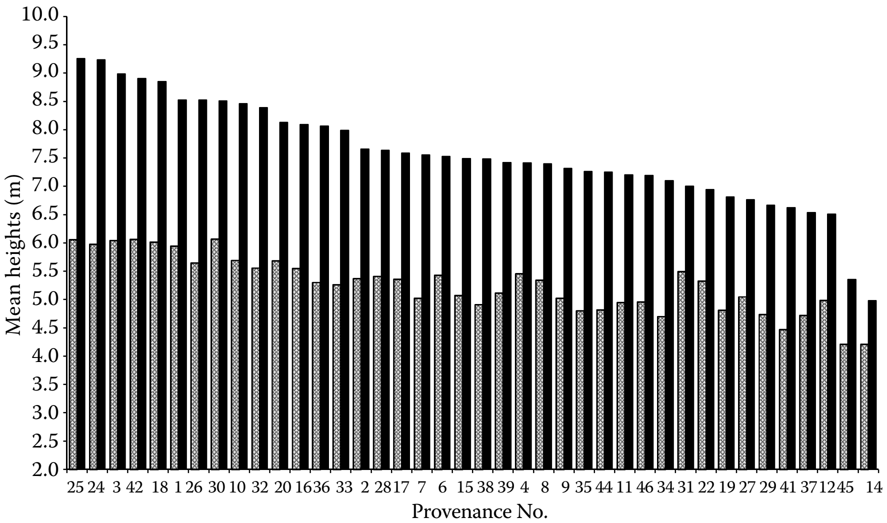

Fig. 1. Comparison mean heights of oak provenances at the plot Malenovice in the age 15 and 20 years. (Provenances of *Q. petraea* are marked in dark)

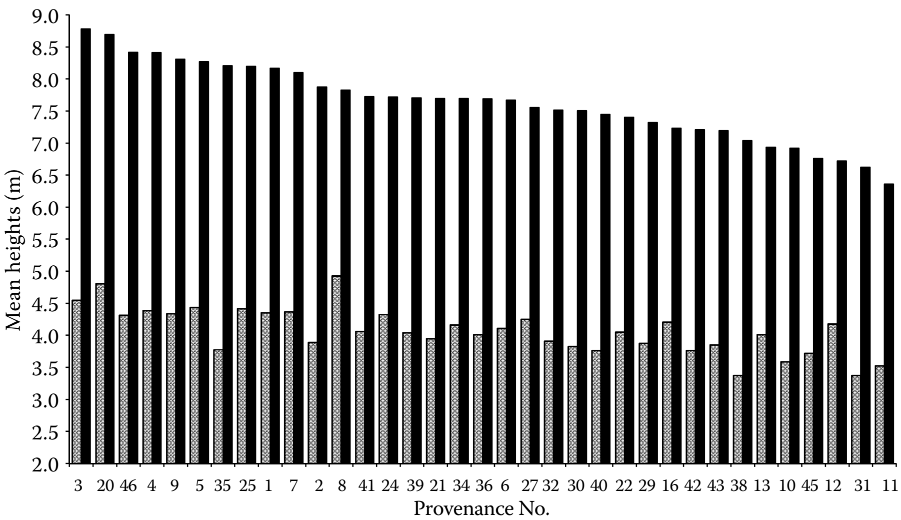

Fig. 2. Comparison mean heights of oak provenances at the plot Netolice in the age 15 and 20 years. (Provenances of *Q. petraea* are marked in dark)

Table 6. Summary statistics of source data on all plots - tree diameter at breast height (cm), provenance without distinction of replication

Provenance No.	Malenovice					Netolice					Plasy					Troubky					Tvrdonice				
	N	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max
													Quercus robur												
1	57	8.86	42.47	3	19	70	6.69	40.55	1	13	37	3.30	57.13	1	8	47	10.68	24.00	6	18	58	9.45	45.43	4	23
3	63	8.35	40.14	4	18	95	6.58	39.64	2	12	76	3.30	62.35	1	15	49	11.00	24.90	5	17	65	8.92	33.23	3	17
4	58	7.47	43.26	3	18	96	6.05	39.86	2	12	74	3.77	52.78	1	12	53	11.02	26.84	6	18	63	8.78	32.83	3	16
5						63	6.33	40.11	1	13						57	10.61	31.13	5	20					
6	68	7.22	43.06	3	15	93	4.92	37.54	2	10	79	4.58	58.33	1	11	50	11.06	29.08	6	21	64	8.33	32.80	3	18
7	79	6.80	35.68	3	15	59	6.03	39.53	1	12	91	2.75	54.96	1	10	54	11.04	26.40	7	20	57	8.09	31.72	3	13
9	76	7.05	37.04	3	14	43	6.65	37.82	2	12	49	4.22	56.61	1	13	48	11.00	25.02	6	17	66	8.56	38.29	3	17
12	77	6.21	39.92	2	12	76	5.13	49.33	1	12	77	3.55	67.64	1	10	39	11.05	28.16	6	22	55	8.05	40.15	3	16
13						74	5.76	38.12	1	10	61	3.72	41.38	1	8	29	10.79	24.93	7	16	49	7.92	30.81	4	14
14	53	5.09	42.74	2	12											43	9.67	25.59	6	16					
15	45	6.96	45.67	2	15											35	9.09	29.77	5	18	41	8.51	33.65	3	17
16	65	7.57	53.36	2	29	97	5.68	42.03	1	12	53	3.30	62.74	1	10	51	10.71	28.96	5	19	64	9.11	32.56	4	20
17	56	7.30	35.70	3	15						51	3.73	59.56	1	10	44	11.11	19.91	7	15	56	8.84	32.42	4	14
18	74	7.61	35.34	3	16						102	2.89	54.16	1	8	52	10.96	25.93	6	20	59	8.69	34.85	3	16
21						82	5.76	38.95	1	11	42	3.67	56.72	1	11	66	10.95	29.89	4	18					
22	69	7.06	56.82	2	19	60	5.65	37.98	1	11	66	3.15	62.54	1	10	44	11.09	27.42	5	20	65	8.71	36.24	3	16
24	73	8.07	42.70	3	21	81	5.17	40.98	2	10	65	4.14	53.33	1	14	56	10.13	23.38	6	15	66	8.98	28.92	4	15
25	74	8.14	35.38	3	18	73	6.26	36.12	2	10						50	11.54	26.27	6	19	61	8.67	31.35	4	14
26	82	7.60	34.97	4	15						86	2.70	48.27	1	6	47	11.43	25.99	7	19	64	8.77	33.07	4	21
27	64	6.67	45.64	3	20	33	7.58	36.15	2	13	44	4.09	46.80	1	8	69	9.97	30.62	5	20					
28	74	7.31	37.13	3	16											49	10.47	25.20	6	18	56	8.88	28.67	4	14
32	80	7.81	38.54	3	17	64	5.42	38.58	2	10	61	2.70	56.61	1	8	44	11.82	20.59	8	17	60	9.05	35.79	4	18
36	61	7.82	34.91	3	15	36	6.64	47.24	1	14	89	2.27	55.48	1	7	63	10.03	28.53	3	16	65	7.20	40.58	3	16
38	56	6.82	43.14	3	14	48	4.98	40.91	1	9	51	3.35	68.75	1	12	41	11.71	24.77	8	20	57	8.05	31.35	3	13

Table 6. to be continued

Provenance No.	Malenovice					Netolice					Plasy					Troubky					Tvrdonice				
	N	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max
													Quercus robur												
40						90	5.03	41.53	1	10						63	9.62	26.43	4	15					
43						94	5.65	42.08	1	13	65	3.65	63.11	1	10										
44	76	6.87	36.32	3	13											43	10.44	25.19	6	16	68	8.10	34.19	4	15
45	48	4.96	48.87	2	12	49	5.37	43.64	1	10	84	2.37	53.55	1	6	46	10.80	24.65	6	18	58	8.03	33.94	3	15
46	67	7.00	39.32	3	15	50	6.28	43.29	1	13						37	11.05	25.04	6	16	55	8.47	31.54	3	14
													Quercus petraea												
2	64	6.94	42.27	2	15	27	5.93	35.93	3	11	98	3.27	67.06	1	11	48	9.27	30.08	2	18	62	6.94	34.43	3	14
8	70	6.97	47.98	3	21	56	6.54	41.97	1	13	63	3.13	50.23	1	9	52	10.17	27.85	5	17	59	9.14	30.39	5	16
10	72	7.68	36.42	3	15	21	5.38	50.72	2	13	56	3.89	53.14	1	10	45	10.44	25.30	6	16	54	7.56	31.35	4	14
11	64	6.14	36.92	3	13	41	4.63	47.95	1	13	118	3.34	66.59	1	12	35	9.09	25.66	6	15	58	6.97	31.82	3	14
19	90	6.14	40.43	3	14											56	9.68	26.81	5	17	64	7.92	34.13	3	14
20	62	7.26	38.80	3	16	28	6.61	41.87	0	12	69	3.58	45.05	1	7	36	10.47	25.16	6	16	58	7.10	29.68	4	12
29	63	5.97	35.86	3	11	14	6.29	49.30	1	11	54	3.50	59.71	1	12	31	9.19	30.17	5	15	65	6.75	35.70	3	13
30	79	7.72	35.13	3	15	25	5.96	42.36	2	13	48	3.85	45.10	1	8	50	9.40	25.43	5	15	54	7.89	37.48	3	17
31	57	7.54	48.71	2	19	26	5.31	49.92	2	15	83	3.64	50.16	1	10	39	10.31	29.96	3	19					
33	72	7.40	37.23	3	14	3	6.67	43.30	0	10	43	4.05	44.13	1	8	52	9.87	27.16	4	17	72	7.19	34.49	3	14
34	69	6.80	44.11	2	15	58	6.64	33.11	2	11	38	3.95	54.29	1	10	39	10.46	29.81	6	18	54	7.94	41.09	3	16
35	68	6.38	43.57	3	16	35	6.57	36.22	3	13	37	3.84	45.34	1	8	42	10.31	27.81	6	17	46	6.93	41.73	3	15
37	69	6.48	39.85	3	14																				
39	62	7.06	44.68	3	15	53	5.83	49.64	1	19	65	3.88	54.24	1	11	34	10.62	29.96	6	21	60	7.72	44.07	3	18
41	53	6.47	39.70	3	13	31	5.87	34.56	1	9	52	4.50	57.97	1	11										
42	82	7.91	30.45	3	14	23	5.65	39.42	1	10	52	3.54	48.29	1	7	43	9.81	22.48	5	16	61	6.93	34.82	3	12

CV – coefficient of variation, min – minimum measured value, max – maximum measured value, *N* – number of trees

Table 7. Summary statistics of source data on all plots - mean height (m), provenance without distinction of replication

Provenance No.	Malenovice					Netolice					Plasy					Troubky					Tvrdonice				
	N	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max	*N*	mean	CV (%)	min	max
	Quercus robur																								
1	57	8.53	20.08	4.5	10.5	70	8.17	29.58	1.7	11.9	37	3.49	42.00	1.5	6.7	47	11.34	15.52	7.5	14.5	58	10.02	15.36	6.0	13.0
3	63	8.98	19.94	5.5	12.0	95	8.78	21.88	3.3	12.1	76	3.48	35.47	1.6	6.9	49	12.08	10.25	8.5	15.0	65	10.06	14.48	5.0	12.0
4	58	7.41	26.02	4.5	10.5	96	8.41	24.08	2.6	12.6	74	3.73	35.85	1.6	7.2	53	12.28	10.64	10.0	15.5	63	9.86	23.61	1.0	13.0
5						63	8.27	28.46	2.5	13.1						57	11.26	15.61	6.0	14.5					
6	68	7.53	20.46	5.0	11.5	93	7.67	26.25	2.7	11.3	79	4.51	36.46	1.5	8.1	50	11.86	13.20	8.5	15.0	64	9.55	15.94	6.0	12.5
7	79	7.56	22.50	5.0	12.5	59	8.10	24.83	1.6	13.2	91	3.26	38.77	1.5	6.1	54	12.04	13.11	7.5	14.5	57	9.16	13.66	5.5	12.0
9	76	7.32	24.57	4.0	12.0	43	8.31	22.98	2.8	12.7	49	3.79	31.07	1.6	6.9	48	11.90	11.92	9.5	15.0	66	9.47	18.45	6.0	13.0
12	77	6.51	29.98	2.5	11.5	76	6.72	35.97	1.8	12.1	77	3.87	40.98	1.6	7.3	39	11.49	13.38	9.0	15.0	55	8.65	22.15	5.5	11.5
13						74	6.94	29.99	2.3	12.1	61	3.90	32.67	1.8	6.9	29	11.07	15.82	8.5	14.5	49	8.55	19.55	4.0	11.0
14	53	4.98	25.96	3.0	8.5											43	10.58	12.41	8.0	14.0					
15	45	7.49	27.10	2.5	9.5											35	10.57	16.59	7.0	14.0	41	9.90	18.32	5.5	12.0
16	65	8.09	28.88	3.0	11.5	97	7.23	26.80	1.8	11.2	53	3.42	34.71	1.5	6.1	51	11.27	13.75	8.0	15.0	64	9.86	16.75	6.0	13.0
17	56	7.59	18.25	5.0	11.0						51	3.82	35.67	1.6	6.3	44	12.09	9.24	10.0	14.5	56	9.93	17.59	5.0	12.0
18	74	8.85	17.51	5.0	11.5						102	3.57	34.20	1.6	7.1	52	11.83	12.39	7.0	14.0	59	10.19	16.66	6.0	13.0
21						82	7.69	27.61	2.4	12.4	42	3.73	29.96	1.7	6.4	66	11.18	17.32	6.0	15.0					
22	69	6.94	28.59	3.0	11.0	60	7.41	26.62	1.7	10.7	66	3.41	32.33	1.5	6.4	44	11.64	15.18	6.5	14.5	65	9.55	19.05	5.5	12.5
24	73	9.23	18.45	5.0	12.0	81	7.72	31.55	1.8	12.7	65	4.43	27.33	1.9	6.7	56	11.80	11.58	9.0	14.0	66	9.92	16.23	6.0	13.0
25	74	9.26	17.43	5.0	12.0	73	8.20	21.78	3.7	11.2						50	12.36	12.74	9.0	15.0	61	10.13	20.11	4.5	12.5
26	82	8.52	17.99	5.0	11.5						86	3.27	29.58	1.6	4.8	47	12.11	11.71	9.0	15.0	64	9.92	14.62	7.0	13.0
27	64	6.77	30.57	1.5	12.0	33	7.55	24.81	2.9	10.7	44	3.94	28.86	1.6	6.1	69	10.80	16.09	6.5	14.0					
28	74	7.64	22.06	4.0	10.5											49	11.59	9.95	9.5	15.0	56	9.95	15.86	6.0	13.5
32	80	8.39	18.63	5.0	11.0	64	7.52	22.84	3.4	11.2	61	3.42	29.67	1.6	5.2	44	12.32	12.23	8.5	14.5	60	9.67	17.00	6.0	12.0
36	61	8.07	17.80	4.0	11.5	36	7.69	35.25	1.5	12.4	89	3.12	33.53	1.6	5.6	63	11.52	13.66	7.0	14.0	65	8.74	19.95	5.0	12.5

Table 7. to be continued

Provenance No.	Malenovice					Netolice					Plasy					Troubky					Tvrdonice				
	N	Mean	CV (%)	Min	Max	*N*	Mean	CV (%)	Min	Max	*N*	Mean	CV (%)	Min	Max	*N*	Mean	CV (%)	Min	Max	*N*	Mean	CV (%)	Min	Max
													Quercus robur												
38	56	7.48	25.74	4.5	11.0	48	7.04	32.65	1.6	12.4	51	3.48	39.88	1.4	6.6	41	12.00	12.22	8.5	14.5	57	9.61	18.10	6.0	12.0
40						90	7.45	29.41	2.3	11.2						63	10.76	17.24	6.0	15.0					
43						94	7.19	28.78	1.8	11.4	65	3.83	40.07	1.6	7.8										
44	76	7.25	17.32	5.0	10.0											43	11.79	13.42	8.0	15.0	68	9.65	18.51	5.5	13.0
45	48	5.35	27.65	3.0	9.5	49	6.76	33.39	1.4	10.2	84	2.68	34.44	1.2	6.4	37	11.65	12.01	8.5	13.5	58	9.29	16.00	5.0	11.5
46	67	7.19	23.37	4.0	10.0	50	8.42	28.74	2.0	12.2						46	11.70	11.38	9.0	15.0	55	9.75	18.76	6.5	13.5
													Quercus petraea												
2	64	7.66	28.62	3.0	12.0	27	7.88	23.79	4.6	12.7	98	3.85	37.41	1.5	7.2	48	11.56	12.60	8.0	15.0	62	8.66	19.61	5.0	12.0
8	70	7.40	31.41	4.0	11.0	56	7.83	24.41	2.3	10.9	63	3.48	31.08	1.5	6.4	52	11.21	16.97	7.5	14.5	59	9.90	15.66	7.0	13.0
10	72	8.46	24.54	5.0	13.0	21	6.92	39.31	2.3	12.4	56	4.29	26.30	2.1	6.9	45	11.91	10.10	9.0	13.5	54	9.56	15.30	6.0	13.0
11	64	7.20	22.83	4.5	10.5	41	6.36	35.43	1.4	11.7	118	3.82	36.10	1.6	7.2	35	11.29	14.35	8.0	15.0	58	9.19	20.33	5.5	13.0
19	90	6.81	24.99	4.5	11.5											56	11.64	15.23	6.5	14.5	64	9.64	20.19	5.5	13.0
20	62	8.13	20.47	4.0	11.0	28	8.70	25.59	0.0	11.8	69	4.13	27.98	1.6	6.8	36	12.33	7.51	10.0	14.0	58	9.10	15.49	5.0	12.0
29	63	6.67	21.04	3.5	9.5	14	7.32	28.30	2.3	9.7	54	3.98	33.27	1.6	7.2	31	11.00	14.08	8.0	14.0	65	8.32	22.49	5.5	12.0
30	79	8.51	17.55	5.0	11.0	25	7.50	25.96	2.9	11.3	48	4.39	25.36	2.0	6.7	50	11.44	14.36	8.0	14.0	54	9.63	16.05	5.0	11.5
31	57	7.00	23.38	3.0	10.0	26	6.62	28.82	3.6	11.6	83	3.88	26.04	1.7	6.3	39	11.03	17.96	5.5	14.0					
33	72	7.99	19.77	4.0	11.5	3	8.23	4.27	0.5	8.6	43	4.22	23.11	2.1	6.1	52	11.73	12.76	8.5	15.0	72	9.44	14.86	6.0	12.5
34	69	7.10	28.49	2.0	11.0	58	7.69	24.82	3.2	11.3	38	3.87	35.62	1.5	6.8	39	11.59	12.32	8.0	15.0	54	9.31	21.15	5.5	12.5
35	68	7.26	21.09	3.5	10.5	35	8.21	29.66	3.2	12.3	37	4.28	27.79	1.9	6.2	42	11.95	11.23	7.5	13.5	46	8.78	23.63	4.5	13.0
37	69	6.54	20.08	3.5	9.5																				
39	62	7.42	22.44	4.0	11.0	53	7.71	35.78	1.5	14.2	65	4.31	30.49	1.4	6.6	34	11.56	14.32	9.0	15.0	60	8.80	24.47	4.5	13.0
41	53	6.62	17.82	4.5	9.5	31	7.73	25.59	1.9	10.6	52	4.63	30.89	1.7	6.5										
42	82	8.90	18.98	5.5	12.5	23	7.21	27.21	2.1	9.4	52	4.02	28.03	1.7	6.2	43	11.60	10.49	9.0	14.0	61	9.28	19.19	5.5	11.5

CV – coefficient of variation, min – minimum measured value, max – maximum measured value, *N* – number of trees

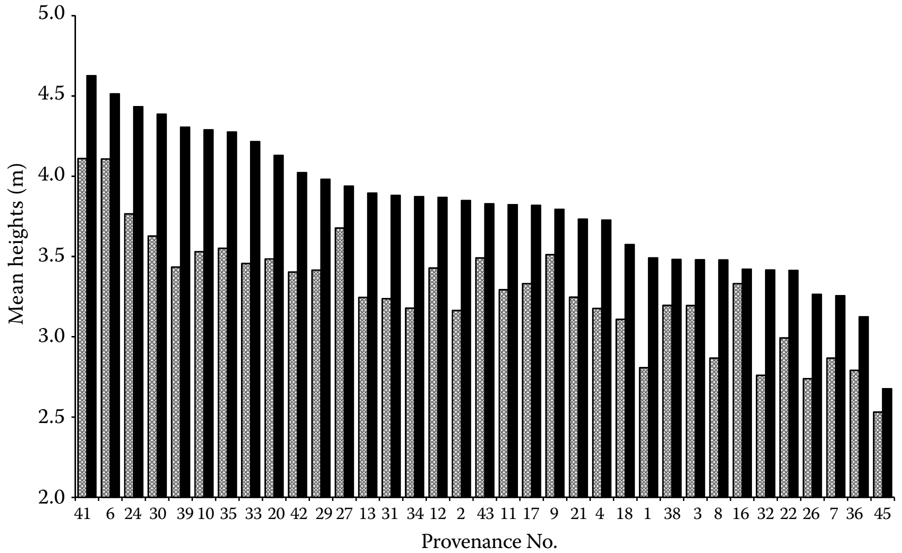

Fig. 3. Comparison mean heights of oak provenances at the plot Plasy in the age 15 and 20 years. (Provenances of *Q. petraea* are marked in dark)

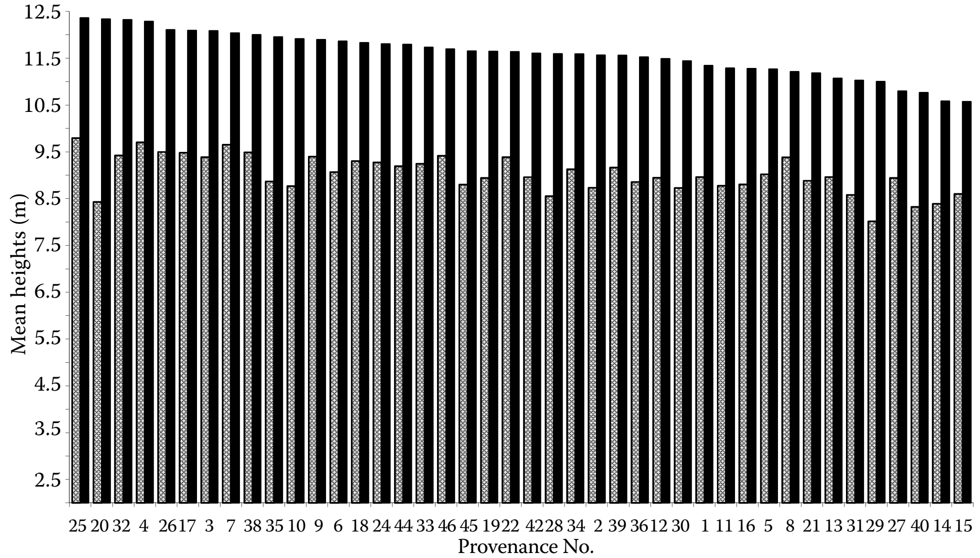

Fig. 4. Comparison mean heights of oak provenances at the plot Troubky in the age 15 and 20 years. (Provenances of *Q. petraea* are marked in dark)

(crown bifurcation) prevails. In the evaluation of the stem shape in both pedunculate and sessile oak mode 2 (gently curved) slightly prevails. Concerning the health condition, the value 2 (poorly damaged) prevails only in pedunculate oak provenance 13 (Litovel). All the other provenances have mode 1 (healthy).

Plasy provenance plot

Based on a comparison of the mean values of tree heights, sessile oak provenances 41 Buchlovice (4.63 m) and 30 Kuřim (4.39 m) and pedunculate oak provenances 6 Písek and 24 Nymburk (4.43 m)

Table 8. The mean values of tree height and breast-height diameter of pedunculate oak and sessile oak on provenance plots

Provenance plot	Mean values					
	pedunculate oak			sessile oak		
	number of trees	height (m)	dbh (cm)	number of trees	height (m)	dbh (cm)
Malenovice	1,595	7.62	7.19	1,096	7.48	6.93
Netolice	1,526	7.69	5.89	441	7.56	5.99
Plasy	1,403	3.63	3.39	876	4.08	3.71
Troubky	1,369	11.60	10.74	602	11.56	9.94
Tvrdonice	1,372	9.62	8.53	767	9.20	7.46

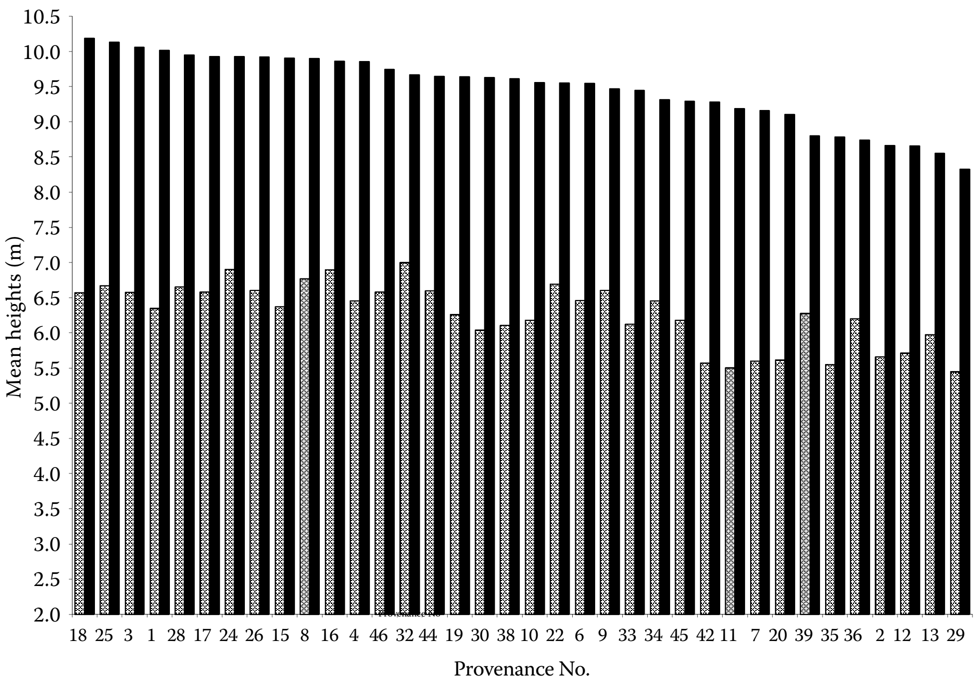

Fig. 5. Comparison mean heights of oak provenances at the plot Tvrdonice in the age 15 and 20 years. (Provenances of *Q. petraea* are marked in dark)

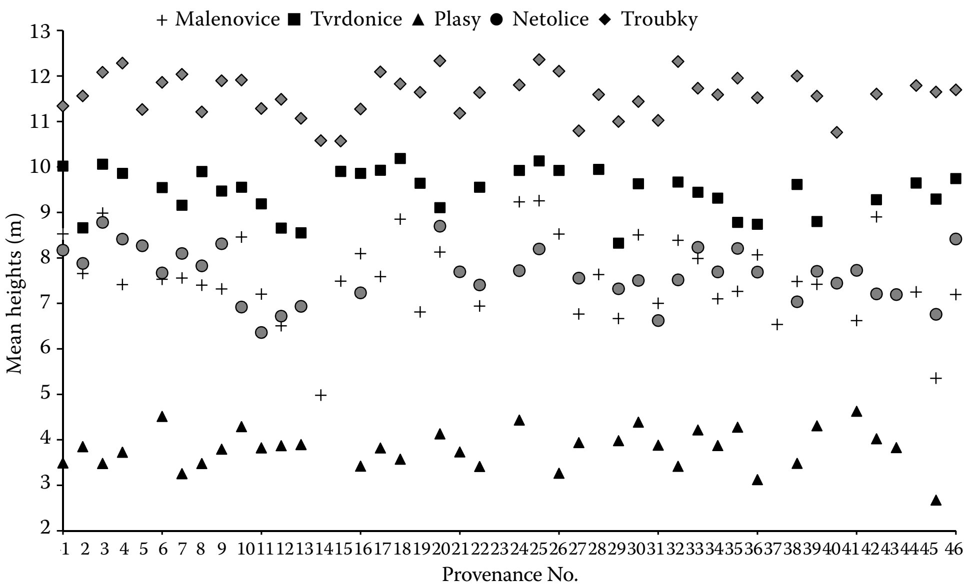

Fig. 6.Comparrison of mean height for the various provenances planted on all plots

were chosen as the best growing, the difference being statistically significant.

The slowest growth was recorded in pedunculate oak provenance 45 Strážnice (mean height 2.68 m), followed by provenances 36 Opava (3.12 m), 7 Vys. Chvojno (3.26 m) and 26 Strážnice (3.27 m).

After comparing the breast-height diameters, pedunculate oak provenance 6 Písek (4.58 cm) and sessile oak provenance 41 Buchlovice (4.5 m) were the best growing ones. The smallest breast-height diameter was measured in pedunculate oak provenance 36 Opava (2.37 cm) and 45 Strážnice (2.37cm).

Mode 2 (crown in the upper third of the stem) for the type of branching is common for all provenances of both oak species except pedunculate oak provenance 21, where mode 3 (crown bifurcation) prevails. Concerning the stem shape evaluation, value 3 (crooked) is the most frequent, which was recorded in all sessile oak provenances. Mode 2 (slightly curved) prevails only in one pedunculate oak provenance. The health condition is characterized by the mode value 1 (healthy) in the case of 25 provenances, 2 (slightly damaged) in the case of 10 provenances, whereas damage is more frequent in pedunculate oak than in sessile oak.

Table 9. Mean, minimal and maximal provenance tree height and breast-height diameter (dbh) on provenance plots

Provenance plot	Number of trees	Height (m)			dbh (cm)		
		mean	min	max	mean	min	max
Malenovice	2,691	7.56	4.98	9.26	7.09	4.96	8.86
Netolice	1,967	7.64	6.36	8.78	5.93	4.63	7.58
Plasy	2,279	3.81	2.68	4.63	3.52	2.27	4.58
Troubky	1,971	11.59	10.57	12.36	10.47	9.09	11.82
Tvrdonice	2,139	9.47	8.32	10.19	8.14	6.75	9.45

Troubky provenance plot

Up to now pedunculate oak provenances 25 Strážnice (12.36 m), 32 Ronov (12.32 m), 4 Mladá Boleslav (12.26 m) and 26 Strážnice (12.11 m) recorded the fastest growth. It is interesting that sessile oak provenance 20 Plasy (12.37 m), which ranked as the second worst 5 years ago, is now the second best considering the mean height. Within the group of the slowest growing provenances pedunculate oak provenances 15 Litovel (10.57 m) and 14 Litovel (10.58 m) predominate. The same provenances but in different order appear among the best growing as well as among the worst growing according to breast-height diameter assessment.

According to both measured parameters, all the provenances on Troubky plot reach the highest values of height and breast-height diameter and differ significantly from the results obtained on the other plots.

Table 10. A list of the fastest growing provenances on particular plots ranked according to the values of height and breast-height diameter

	Provenance plot	Order									
		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Mean height (m)	Malenovice	25	24	3	42	18	1	26	30	10	32
	Mean	9.26	9.23	8.98	8.90	8.85	8.53	8.52	8.51	8.48	8.39
	Netolice	3	20	46	4	9	5	35	25	1	7
	Mean	8.78	8.70	8.42	8.41	8.31	8.27	8.21	8.20	8.17	8.10
	Plasy	41	6	24	30	39	10	35	33	20	42
	Mean	4.63	4.51	4.43	4.39	4.31	4.29	4.28	4.22	4.13	4.02
	Troubky	25	20	32	4	26	17	3	7	38	35
	Mean	12.36	12.33	12.32	12.28	12.11	12.09	12.08	12.04	12.00	11.95
	Tvrdonice	18	25	3	1	28	17	24	26	15	8
	Mean	10.19	10.13	10.06	10.02	9.95	9.93	9.92	9.92	9.90	9.90
Mean dbh (cm)	Malenovice	1	3	25	24	42	36	32	30	10	18
	Mean	8.86	8.35	8.14	8.07	7.91	7.82	7.81	7.72	7.68	7.61
	Netolice	27	1	9	36	34	20	3	35	8	5
	Mean	7.58	6.69	6.65	6.64	6.64	6.61	6.58	6.57	6.54	6.33
	Plasy	6	41	9	24	27	33	34	10	39	30
	Mean	4.58	4.50	4.22	4.14	4.09	4.05	3.95	3.89	3.88	3.85
	Troubky	32	38	25	26	17	22	6	45	12	7
	Mean	11.82	11.71	11.54	11.43	11.11	11.09	11.06	11.05	11.05	11.04
	Tvrdonice	1	8	16	32	24	3	28	17	4	26
	Mean	9.45	9.14	9.11	9.05	8.98	8.92	8.88	8.84	8.78	8.77

The value for sessile oak are underlined

For the qualitative trait of the type of branching mode 2 (crown in the upper third of the stem) entirely prevails; only in the case of sessile oak provenance 20 mode 1 (continuous stem) was recorded. Concerning the stem shape, evaluation 2 (slightly curved) slightly prevails in 24 provenances, evaluation 1 (quite straight) in the case of 10 provenances, and 3 (crooked) in 8 provenances. The health condition was evaluated as mode 1 (healthy) in all cases.

Tvrdonice provenance plot

Pedunculate oak provenances 18 Opočno (mean 10.19 m), 25 Strážnice (10.13 m), 3 Litovel (10.86 m) and 1 Strážnice (10.02 m) appear as the best growing group in terms of their height. Sessile oak provenance 29 Znojmo (8.32 m) and Bučovice (8.66 m) and pedunculate oak provenance 12 Litovel (8.55 m) and 12 Křivoklát (8.62 m) were found to be the slowest growing. Mode 2 (crown in the upper third of the stem) entirely prevails for the type of branching. Only in the case of provenance 30 the majority of the stems were classified as quite straight – mode 1. The results of the stem shape evaluation document that five provenances of sessile oak and four provenances of pedunculate oak had the highest proportion of straight stems. For the majority of the provenances (20) evaluation 2 (slightly curved) prevails, for 7 provenances mode 3 (crooked). Healthy trees – evaluation 1 prevails in all provenances.

Results of comparison of differences among plots

In Table 5 the assessment of differences among the particular plots in height and breast-height diameter is given. ANOVA was used for data processing. The results of Dunnett's *a posteriori* test ($P < 0.05$) are presented. The order of the localities is according to the mean descending value, significant differences are marked by the sign (>), and localities without significant difference are divided by the sign (",").

The lowest values of height and breast-height diameter were found out on the provenance plot Plasy for all provenances. The highest values were recorded on Troubky plot. The results from the plots Malenovice and Netolice were relatively very close (in most cases they were not statistically significant and lower than on Tvrdonice plot). The differences among particular site conditions are most probably the main reason and in the case of floodplain woodland the grain size of the sediments can also be considered. Also the influence of different silvicultural treatments of plants in the first years after their outplanting came out partially, e.g. on Plasy plot.

Results of comparison of differences among provenances

Table 10 shows the order of the 10 best growing provenances on particular plots according to the values of height and breast-height diameter.

In pedunculate oak, provenance 26 Strážnice, originating from the aeolian sands of Hodonín area, seems to be the best provenance according to mean height. This provenance is the highest on the plots Troubky and Malenovice, the second highest on Tvrdonice plot, and it was recorded within top ten on Netolice plot. On Plasy plot it was not planted at all. Quite good results were also obtained in provenance 3 Litovel, where it reached the tallest height, on the plots Malenovice and Tvrdonice it was the third and on Troubky plot it was also among the best ten. Among the sessile oak provenances provenance 20 recorded the best results. It was the second best on the plots Netolice and Troubky, the ninth on Plasy plot, the eleventh on Malenovice plot. A worse result was recorded only on Tvrdonice plot.

DISCUSSION AND CONCLUSIONS

The forest management planning (Průša 2001) sets the rotation period for oak 120 to 160 years. When we compare the age of oak provenance plots with the assumed rotation period, it is necessary to take into account the limited reliability of our conclusions and the importance of the choice of monitored traits. Indicated circumstances reflect that the results from the evaluation of 20 years old provenance trials should be interpreted very carefully, and it is nevertheless useful to take into account other factors (knowledge of the natural site conditions, stand development etc.).

Tree height appears to be the most important trait for the assessment of growth of individual oak provenances at the age of 20 years. Therefore it was chosen as the main criterion for our conclusions. This value decides on stand development in the initial phase, how the tree species will be successful at the tested site. Other characteristics (breast-height diameter, type of branching, stem shape and health condition) are presently of only minor importance but they will become more significant with the aging of trees.

Based on the results of evaluation excellent provenances have been chosen which recorded the best results in this growth phase and can therefore be presented as proved units. As for pedunculate oak, these are provenances 25 (Strážnice – Hodonín), 3 (Litovel – Březová), 24 (Nymburk – Dymokury), 18 (Opočno – Mochov), 1 (Strážnice – Kunovice), and 32 (Ronov – Choltice). In the case of sessile oak these are the provenances 20 (Plasy – Doubrava), 41 (Buchlovice – Koryčany) and 35 (Jaroměřice n. R. – Rozkoš).

A comparison of the species indicates that pedunculate oak at young age grows better than sessile oak on humid deep fertile soils in the lowland, where sessile oak grows worse especially in the floodplain, but these differences were not proved statistically. The worse growth of sessile oak at floodplain sites can be explained by low tolerance to high levels of groundwater. On the contrary, it tolerates much better dry climatic and soil conditions in comparison with pedunculate oak (Úradníček et al. 2009). The differences in the growth of the two species result from their ecological requirements.

However, on the basis of the evaluation the differences within both species among the plots and provenances were significant. Differences in the stem shape were very large. The straight stem was observed in some provenances in up to 56% of individuals, on the other hand in some provenances it was not recorded at all.

Summarizing the results of provenance experiments with pedunculate and sessile oaks has shown that some provenances are more adaptable to the site conditions, have lower losses and a very good growth potential. The differences among provenances of pedunculate or sessile oak far exceed the differences among ecotypes. The differences in the stem quality among provenances are very large already in the early growth phase.

Numerous provenance experiments were established in many European countries – e.g. in Switzerland (Burger 1949), Russia (Shutyaev, Pozdorovkina 1983), Romania (Niţu, Ratiu 1987), Croatia (Gračan 1993; Vidakovič et al. 2000), Slovakia (Šimiak 1994), Netherlands (Jensen et al. 1997), Poland (Fober 1998), Germany (Maurer et al. 2000), but usually only at single places and on a small scale, because of the difficulty of co-ordinating viable seed transfers (Giertych 2006). Therefore it is mostly difficult to compare the relative performance of populations in various localities, in addition also due to different experimental conditions and different provenances used.

The obtained results confirm the experience from oak provenance testing in Germany and Denmark, where pedunculate oak at young age thrives better than sessile oak at its typical natural site (Svolba, Kleinschmit 1995, Jensen 2000, Kleinschmit, Kleinschmit 2000, Kleinschmit, Svolba 2000). According to these authors the differences disappear later around the age of 40 years.

References

Anonymus (2009): Report on The State of Forests and Forestry in the Czech Republic in 2008. Praha, MZe: 128. (in Czech)

Benedíková M. (2000): The first evaluation results of testing plots of certified oak units. Communicationes Instituti Forestalis Bohemicae, ***82***: 143–157.

Benedíková M. (2003): The evaluation results of 15-year old provenance plots with oak. Zprávy lesnického výzkumu, ***48***: 172–185. (in Czech)

Burger H. (1949): Influence of seed origin on properties of forest growth. Communications VII. Oaks. Mitteilungen der Schweizerischen Anstalt für das forstliche Versuchwesen, ***26***: 59–90. (in German)

Fober H. (1998): Provenance experiment with pedunculate (*Quercus robur* L.) and sessile (*Quercus petraea* [Matt.] Liebl.) established in 1968. Kornik, Arboretum Kórnickie: 67–78. (in Polish)

Giertych M. (2006): Population genetic. In: Bugała W. (ed.): Our forest trees: Popular science monography. Volume 11, Oaks: *Quercus robur* L., *Quercus petraea* (Matt.) Liebl. Poznań, Kórnik, Polska Akademia Nauk, Instytut Dendrologii: 591–639.

Gračan J. (1993): Preliminary results of common oak (*Quercus robur* L.) provenance experiments in Croatia. Annals of Forest Science, ***50*** (Supplement 1): 215–221.

Jensen J.S. (2000): Provenance variation in phenotypic traits in *Quercus robur* and *Quercus petraea* in Danish provenance trials. Scandinavian Journal of Forest Research, ***15***: 297–308.

Jensen J.S., Wellendorf H., Jager K., De Vries S.M.G., Jensen V. (1997): Analysis of a 17-year old Dutch open-pollinated progeny trial with *Quercus robur* L. Forest Genetics, ***4***: 139–147.

Kleinschmit J., Kleinschmit J.G.R. (2000): *Quercus robur – Quercus petraea*: a critical review of the species concept. Glasnik za šumske pokuse, ***37***: 441–452.

Kleinschmit J., Svolba J. (1995): Intraspecific variation of growth and stem form at *Quercus robur* und *Quercus petraea*. Mitteilung aus der Forstlichen Versuchsanstalt Rheinland-Pfalz, ***34***: 75–99. (in German)

Maurer W.D., Tabel U., Kőnig A.O., Stephan B.R., Müller-Starck G. (2000): Provenance trials of *Quercus robur* L. und *Quercus petraea* (Matt.) Liebl. in Rhineland-Palatinate. Preliminary results of phenotypic and genetic surveys. Glasnik za šumske pokuse, ***37***: 329–345.

Niţu C., Raţiu M. (1987): Contributions to knowledge of common oak provenances variability studied in definitive comparative cultures. Bulletin de l' Academie des Sciences, ***16***: 67–80.

Plíva K. (1991): Typological Classification of Forests in the Czech Republic. Brandýs nad Labem, Lesprojekt: 117. (in Czech)

Plíva K., Žlábek I. (1986): Natural Forest Regions in the Czech Republic. Praha, SZN: 313. (in Czech)

Průša E. (2001): Forest Silviculture on Typological Principles. Kostelec nad Černými lesy, Lesnická práce: 593. (in Czech)

Prudič Z. (1992): Replacement of oak by beech in the Moravian Carpathians. Lesnictví-Forestry, ***38***: 145–153. (in Czech)

Svolba J., Kleinschmit J. (2000): Differences among provenances of oak decline. Forst- und Holzwirt, ***55***: 15–17. (in German)

Shutyaev A.M., Pozdorovkina O.B. (1983): The evaluation of oak planting grown from acorns of different origin. Lesnoje chozjajstvo, ***11***: 28–31. (in Russian)

Šimiak M. (1994): The comparison results of oak provenance growth (*Quercus robur* L. and *Quercus petraea* Liebl.) on the research plot Kajlovka. Zprávy lesnického výzkumu, ***39***: 5–11. (in Slovak)

Úradníček L., Maděra P., Tichá S., Koblížek J. (2009): Woody Species of the Czech Republic. Kostelec nad Černými lesy, Lesnická práce: 367. (in Czech)

Vidakovič M., Kajba D., Bogdan S. Podnar V., Bečarevič J. (2000): Estimation of genetic gain in a progeny trial of pedunculate oak (*Quercus robur* L.). Glasnik za šumske pokuse, 37: 375–381

Received for publication October 26,2010
Accepted after corrections February 14, 2011

Corresponding author:
RNDr. Václav Buriánek, Forestry and Game Management Research Institute, Strnady 136, 252 02 Jíloviště, Czech Republic
e-mail: burianek@vulhm.cz