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Quantitative and qualitative evaluation of Northern red oak (*Quercus rubra* L.) in arid areas of North-Western Bohemia

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Abstract

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The article analyses growth and quality of Northern red oak (*Quercus rubra* Linnaeus) based on 13 research plots (seven in red oak stands and six in sessile oak stands) with the ages between 17 to 159 years. The collected data includes height, DBH, crown diameter, stem and crown quality, health status of each tree on the plot. Analogous plots were chosen in sessile oak (*Quercus sessilis* Linnaeus) stands on similar sites to get reference data. The results proved the high wood production potential of red oak when compared to sessile oak being at the same or higher quality and health. The data propose the red oak to be a good additional species in lowland stands.

Keywords: exotic oak; domestic oak; growth; tree quality; stand quality; health status

Northern red oak (*Quercus rubra* Linnaeus) is one of the most important introduced species in the Czech Republic. It occupies the stand area of 5,131 ha which represents 0.20% of the total forest stand area and its growing volume is about 900,000 m^3 (forest inventory data as of 2016).

Many authors confirm the high volume production of red oak when compared to domestic oaks (Seidel, Kenk 2003; Kouba, Zahradník 2011; Podrázský et al. 2014). Red oak is an undemanding species in terms of site quality (Kim et al. 1995). It is highly tolerant to environmental stresses (Burkovský 1985) and therefore it could be used for afforestation of degraded areas (Holubík et al. 2014; Vopravil et al. 2014) as well as for afforestation of former agricultural lands (Podrázský, Štěpáník 2002; Vopravil et al. 2015) together with other species (Bartoš et al. 2015). Red oak has – like the other broadleaved species – a positive influence on soil horizons (Podrázský, Remeš 2010) or at least not distinctly worse (Miltner et al. 2016; Miltner et al. 2017). Its strong regeneration capacity could be used for reforestations of old clear-cut areas with dense weeds (Loftis 1990; Healy et al. 1999; Lanham et al. 2002; Küßner et al. 2003; Frey et al. 2007; Craig et al. 2014; Myczko et al. 2014). It is suspected of being an invasive species in Europe but so far there has not been any proof of that (Spiecker 2006; Major et al. 2013; Miltner, Kupka 2016); on the other hand, many authors found some difficulties in its regeneration in native North America (Zhou et al. 1997; Spetich et al. 2002; Oliver et al. 2005).

Red oak has nice leaves and wonderful habitus which are highly evaluated in parks and urban forestry.

The aim of the work is to evaluate the quantitative and qualitative parameters of red oak stands

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Table 1. Basic data on research plots

Plot No.	Forest district	Stand	Age (yr)	Forest type	Altitude (m a.s.l.)	Stand height (m)	DBH (cm)	Species
1	Holedeč	445C1c	17	2K1	219	9	7	red oak
2		452G1b	17	2S6	219	5	4	sessile oak
3	Slavětín	341A2c	24	1C2	230	8	7	red oak
4		341A2c	24	1C2	230	8	6	red oak
5		341A2b	24	1C2	230	9	7	sessile oak
6	Horní Beřkovice	736A4b	49	1S6	276	16	13	red oak
7		733D5b	50	1K1	297	18	15	red oak
8		733D5b	50	1K1	272	18	15	red oak
9		736A7	73	1S6	275	20	25	sessile oak
10		734D11b	111	1S6	280	19	25	sessile oak
11	Peruc	337B10	103	1S6	300	24	28	red oak
12		338D15	159	1C2	329	21	38	sessile oak
13	Budyně-Levousy	325A5c	56	2S5	270	16	17	sessile oak

within the possibly entire rotation period. The analogous data collected in sessile oak stands were used as reference data.

MATERIAL AND METHODS

The research plots were created in pure red oak stands whose ages covered the time period as long as possible from 17 to 159 years. The plots are on the same or similar site types (acid and/or poor) containing at least 100 trees and avoiding edges of the stand. Similar series in sessile oak stands were established to create pairs of the same (or similar) age for both species. The total number of plots was 13, 7 plots of red oak and 6 plots of sessile oak. Basic information on research plots is given in Table 1.

The stands of both species on plots were managed in the same way according to the forest management plan prescriptions.

The basic dendrometric data were collected for each tree, i.e. DBH (in two perpendicular directions measured with a calliper with precision of mm), height measured with precision of 0.1 m, crown diameter measured in two perpendicular directions (the orientation of crown diameter was always the same orientated according to north and south), crown length with precision of 0.5 m and tree position according to Kraft's tree classes. The total tree volume under bark thicker than 7 cm (merchantable volume) was calculated using Halaj's formula (Halaj et al. 1981).

The number of trees is a stand characteristic which is mostly influenced by a forest manager. The differences occurred in a new plantation which is controlled by regulations. However, the intensity of thinning is the main control tool influencing not only the number of trees but also the competitive conditions within the stand. Yoda et al. (1963) proposed the evaluation of a relationship between the number of trees and their size (height, diameter, biomass etc. of average single tree); due to logarithmisation of the number of trees the evaluation of the relationship is easier. Dendrometric data are regressed by linear, polynomic or Korf's functions according to their characters. The floor plan of the crown area of each tree was calculated as an elliptical or circular area.

The tree and stem quality assessment was done according to Table 2.

Also stem rotations, branch strength, and bark quality were evaluated for each tree on the plot (Table 3).

Data were processed in STATISTICA (Version 13.1, 2017) where basic statistics were calculated. Cases where statistically significant differences make sense were evaluated by one-way ANOVA.

Table 2. Stem and crown quality assessment (Frýdl et al. 2009)

Label	Stem	Crown
1	straight high quality	symmetric fully developed
2	slightly bent	asymmetric fully developed
3	s-curved	deformed fully developed
4	bent stem or twin	undeveloped, flattened
5	poorly growing	combination of previous

Table 3. Assessment of stem rotations, branch strength, and vitality and health status

Label	Twisted stem	Branch diameter[1]	Health status
1	no rotation	thin (< 0.1)	healthy, vital
2	rotated	middle (< 0.2)	not vital
3	–	thick (> 0.2)	dying

[1]relative branch diameter as a ratio between branch and stem diameter

After checking the normality of data post-hoc Scheffe's test was used to evaluate the significance of differences at the probability level α = 0.95.

RESULTS AND DISCUSSION

The number of trees per hectare is given at reforestation by Decree No. 83/1996 Coll. at the start. Natural mortality as well as thinning started lately to regulate the number of trees according to their growth (size). Fig. 1 shows slight differences between the two species with the non-significantly higher number of red oak trees in the second half of the rotation period (stand height more than 15 m).

The data in Fig. 1 show that red oak is a flexible species in space requirements which was stated by practitioners and by many authors as well (Réh 1967; Remiš 1982; Réh, Réh 1997). Therefore red oak seems to have a capacity for the thinning method where thinning is not applied on the whole stand area but on selected trees areas (Korpeľ 1974; Remiš 1988; Štefančík 1991, 2011c).

The high number of trees has adversely affected slenderness ratio and diameter increment. Both red oak and sessile oak stands have the slenderness ratio higher than 100 in young stands (Fig. 2). The value 100 is considered as a threshold for potential damage by wind and heavy wet snow (Vicena et al. 1979; Slodičák, Novák 2007; Dušek et al. 2011; Novák et al. 2013).

However, oak stands are in lowland where no wind and snow damage in early autumn or spring occurs.

Data in Table 4 shows the relative superiority of red oak stands in terms of stem and crown quality as well as vitality and health status. Even though the data represents only a few stands, it illustrates clearly that red oak stands if properly managed are not of lower quality (Štefančík 1992; Spiecker 2006; Štefančík 2011a, b; Slávik, Štefančík 2015) as some studies proposed (Gubka, Sklenár 2006; Gubka, Pittner 2014).

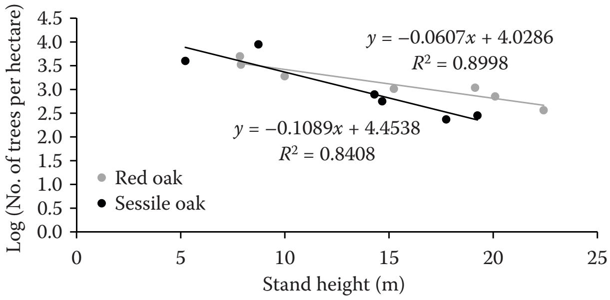

Fig. 1. No. of red and sessile oak trees per hectare expressed as a relationship between stand height and logarithm of number of trees per hectare

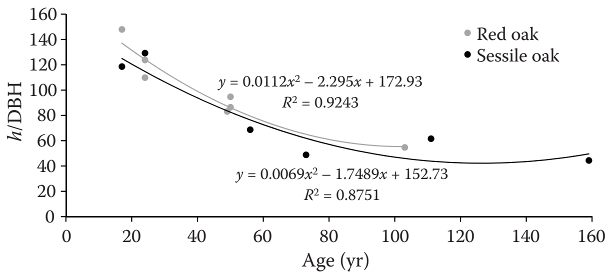

Fig. 2. Average development of slenderness ratio in red and sessile oak stands

Significant predominance of red oak in height growth is evident in Fig. 3a, namely in the second half of the rotation period (i.e. after its 60 years age) specifically for red oak stands of higher tree classes (main stand).

Similarly, the stand diameter reports the predominance of red oak stands over sessile oak stands in the second half of the rotation period – i.e. after its 60 years age (Fig. 3b). The situation is opposite

Table 4. Quality and health status of sessile and red oak stands on research plots

Species	Age (yr)	Health status, vitality	Branch diameter	Quality		Twisted stem
				crown	stem	
Sessile oak	17	1.04	2.29	1.78	1.21	1.21
	24	1.15	2.09	1.76	1.11	1.11
	56	1.34	1.57	1.97	1.05	1.05
	73	1.43	2.16	2.23	1.03	1.03
	111	1.63	1.99	2.45	1.00	1.00
	159	1.25	2.18	1.67	1.00	1.00
Red oak	17	1.05	1.72	1.60	2.68	1.05
	24	1.02	179	1.68	2.37	1.02
	49	1.65	1.71	2.38	2.36	1.00
	50	1.64	1.89	2.17	1.92	1.05
	103	1.00	2.02	1.52	1.94	1.00

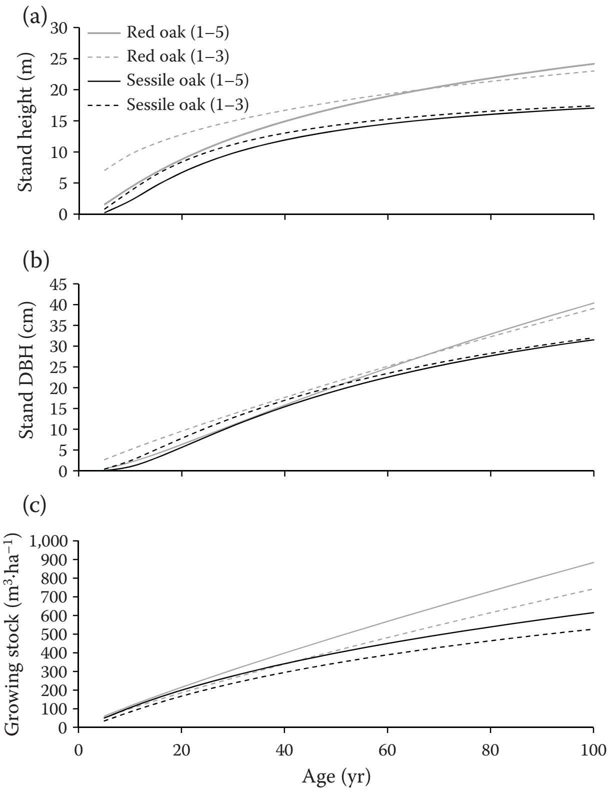

Fig. 3. Red and sessile oak stand height (a), diameter (b), total volume of growing stock under bark thicker than 7 cm (c); full line for the whole stand: tree classes 1–5, dashed line for main stand: tree classes 1–3

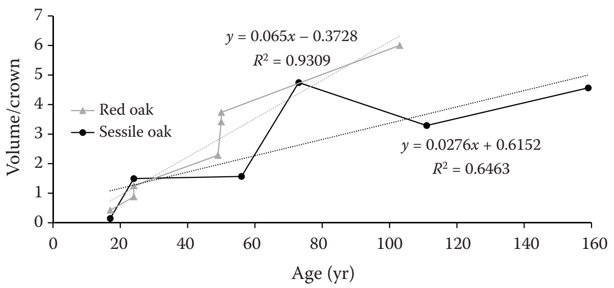

Fig. 4. The relationship between the floor plan of the crown area and volume production for red and sessile oak

in the first half of the rotation period due to the higher stand density of red oak.

Again, the predominance of red oak is manifested in the second half of the standing volume production (Fig. 3c), which is higher, not only compared to sessile oak (Štefančík 2012) but also compared to most domestic tree species (Pulkrab et al. 2015).

An important parameter is also the performance of the assimilation apparatus of the crown, which can be assessed according to the volume of growing stock per unit of crown area measured on the floor plan (Poleno 1984). This parameter expresses the growth effectivity of the species in the available space (Fig. 4).

Fig. 4 shows the superiority of red oak in volume production per available space unit which is significantly higher than that for sessile oak. The parameter and its evaluation are important characteristics of the species (Poleno 1984).

CONCLUSIONS

Red oak proved to be a productive species which has the same or better quality (Table 4) and better growth (Figs 3a, b). Red oak has higher volume production not only in terms of single tree volume related to the crown size (Fig. 4) but also per hectare (Fig. 3c). It could be a possible alternative for domestic oak where it could not be used for sanitary or other reasons.

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