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Unearthing the hidden domain of epicormic shoots: Insights into forest management impacts on *Quercus petraea* (Matt.) Liebl.

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Abstract: Forest management of durmast oak stands [*Quercus petraea* (Matt.) Liebl.] is focused on the production of high-quality assortments for the furniture industry. Due to various forest management factors and impacts of climate change, their vitality and quality are often reduced. Sudden illumination of the oak trunk caused by management cuts can lead to epicormic shoot formation. This study compared two localities and nine long-term research plots at the stand age of 62–68 years in Slovakia. While one locality was affected by the massive dieback of oak in the past, the other was not. The epicormic shoot occurrence was monitored separately in the lower and upper parts of the trunk, depending on selected quantitative tree parameters and on the various management methods. The formation of epicormic shoot was influenced especially by *DBH*, crown width and crown volume. The occurrence of shoots was always markedly higher in the upper part of the trunk compared to the lower one. During a 35-year period, the development of the proportion of epicormic shoots in the lower part of the trunk in the locality with massive dieback of oak confirmed a higher occurrence on control plots compared to the managed plots with thinning interventions. It showed that the occurrence of epicormic shoots in durmast oak stands was influenced not only by different methods of management but also by the dieback effect in the past. Promoting more intensive thinning in early-stage oak stands is advised, as it prompts trees to develop larger crowns with limiting formation of epicormic shoots.

Keywords: dieback effect; durmast oak; economic looses; stand density; thinning

Oaks (*Quercus* sp.) belong to the most important deciduous tree species in Europe, both from an economic and environmental point of view (Podrázský, Kupka 2024; Miltner et al. 2017; Mölder et al. 2019; Stavi et al. 2022; Šimková et al. 2023; Ábri et al. 2025). This species is mostly represented in forest stands of the lower to mid altitudes (Eaton et al. 2016; Vančura et al. 2022). The cultivation of durmast oak [*Quercus petraea* (Matt.) Liebl.] is a part of the landscape forest

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management, and this is also reflected in the long-term influence of this tree species on the habitat (Von Oheimb et al. 2008; Nicolescu et al. 2025; Žižková et al. 2025). This oak was cultivated in the past both from copies and as a high forest and belongs to the tree species that can adapt to climatic fluctuations (Vacek et al. 2018a, 2019; Kadavý et al. 2019). However, in recent years, oak forest stands have been increasingly exposed to the adverse effects of long-term drought, frequent heat waves and other abiotic extremes. This is most often connected with ongoing global climate change (Keenan 2015; Seidl et al. 2017; Vacek et al. 2020, 2023). As a result, oak stands are often physiologically weakened, especially by drought stress, which is visibly reflected in a reduction of their vitality and tolerance to various harmful factors (Zúbrik et al. 2019; Černý et al. 2024). Oak stands have also been historically affected by various adverse factors; for example, during the 1970s and 1980s, widespread oak dieback associated with fungal tracheomycosis was reported (Jakucs 1988; Čapek et al. 1985; Gaertig et al. 2002; Thomas et al. 2002). Although this disease was known in various European countries from the past (Eisenhauer 1989; Siwecki, Ufnalski 1998; Bobinac, Andrašev 2001; Leontovyč et al. 1987; Malaisse et al. 1993), in this period, not only in Slovakia, it acquired the character of a disaster.

Although later at the turn of the 1980s and 1990s, the massive dieback of oaks decreased significantly, and in some less affected stands, their revitalisation and regeneration became evident; nevertheless, the consequences also resulted in economic losses, especially in the volume production (Račko et al. 1987). Although the emphasis was laid on quantitative production in these oak stands (mixed and pure ones) (Krahl-Urban 1959; Venet 1967; Baksa 1970; Korpeľ 1981), the main goal is mainly the production of high-quality assortments (Schütz 1993; Chroust 2007; Štefančík 2012; Gubka, Sklenár 2006; Slodičák et al. 2009). Species mixing in oak stands can increase resilience to climate change, although it generally has relatively small effects on overall stand growth, and oaks in mixed stands exhibit significantly wider crowns than in monocultures (Pretzsch et al. 2020), which may also substantially affect timber quality. High-quality assortments can be achieved by a suitable tending method, especially in the youngest growth phases (Korpeľ 1981; Chroust 1997; Slodičák et al. 2009; Dušek et al. 2011; Sloup et al. 2019). Economic losses in the context of trunk quality deterioration can be caused especially by the formation of epicormic shoots (Bárdos et al. 2015). When epicormic shoots are left uncontrolled after thinning a stand, the value of the timber for veneer purposes can be downgraded by up to 90% (Lorrain-Smith 1972; Wignall et al. 1987).

The formation of epicormic shoots in the oak stands is caused by the canopy opening, which is created by the lightening of the crown, either as a result of natural influences or thinning interventions (Kerr 1996). The epicormic shoots are created by the heat on the surface of the bark as a result of higher illumination, where epicormic shoots emerge from epicormic buds (Wignall, Browning 1988). A frequent manifestation of declining vitality or deteriorating health conditions in oak stands is an increased occurrence of epicormic shoots (Jakucs 1988; Thomas et al. 2002). When performing the tending of oak stands, it is necessary to consider the properties of this tree species, which are longevity, susceptibility to slenderness and a considerable tendency to spread branches after a large release of the canopy, especially at a young age. Compared to other tree species, oak has a high predisposition to form epicormics (Harmer 1990; McDonald, Ritchie 1994; Morisset et al. 2012).

Pioneer (nurse) tree species (beech, hornbeam, linden, maple) play an important role in this context. Their role is to prevent the epicormic shoots, to limit the formation of wide crowns of the main stand and to support the cleaning of trunks and the formation of high-set crowns (Štefančík 2011; Hurt 2012; Attocchi 2015; Slávik, Štefančík 2015; Poleno et al. 2009). Pioneer species in the suppressed level (understorey) of the stand also improve site conditions, so their occurrence is considered important from an ecological point of view (Leibundgut 1945; Korpeľ 1981; Hochbichler 1993; Chroust 1997).

In connection with the issue of epicormics, several experiments were performed from various aspects. Kerr and Harmer (2001) studied the effect of the frequency and time of pruning on epicormic shoot populations in two stands of English oak (*Quercus robur* L.) for three consecutive years. Harmer (1990) was monitoring the development of English oak buds on branches and on the trunk for two years in relation to the occurrence of epi-

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cormics. Morisset et al. (2012a, b) investigated the relationship between epicormics formed near the trunk pith and epicormics on the bark surface using X-ray computed tomography. Most observations were focused on epicormic research in relation to different tending and pruning methods (Attocchi 2013; McDonald, Ritchie 1994; Pretzsch, Utschig 1995; Howell, Nix 2002; Buresti et al. 2000; Colin et al. 2010).

In Central Europe, oak forests are becoming increasingly important primarily due to the growing emphasis on oak afforestation and regeneration (Cukor et al. 2017a, b, 2022; Vacek et al. 2018b), driven by changing wood-industrial management measures towards climate-change adaptation strategies, while their ecological tolerance to drought and changing conditions forms a supporting background to this trend (Fürst et al. 2007). This paper is to compare and evaluate the epicormic shoot occurrence in two oak stands in Slovakia, where oaks are the second most widespread deciduous tree species, accounting for 10.2% of the forest land (MARD SR 2025). The epicormic shoots are evaluated in management and naturally (thinning versus no intervention) developed oak sites in the context of different damage and massive dieback of oak in the past. The aim of this study is to evaluate the effects of different forest management practices on stand quantitative parameters, analyse the occurrence of epicormic shoots on the upper and lower parts of the trunk over time, determine the relationships between tree parameters (diameter, crown width, and crown volume) and their formation, and compare stand responses across sites with different histories, health conditions and structures, with the goal of optimizing management to improve timber quality and reduce undesirable epicormic shoot development.

MATERIAL AND METHODS

Study sites. Two durmast oak stands with established long-term research plots (LTP) were chosen as the object of the research (Table 1). One is located in central Slovakia (Veľká Stráž). This stand originated from natural regeneration of the oak parent stand with mixed European hornbeam (*Carpinus betulus* L.) by applying uniform shelterwood felling. This LTP was established in 1973 at the age of 19 years (Baksa 1975). The LTP series consists of 6 subplots: P1, P2, P3, where, since

Table 1. Site characteristics of the investigated research plots

Name (plot/subplot)	No. of measurements	Time period of measurements	Age span (years)	GPS location	Elevation (m a.s.l.)	Mean annual temperature (°C)	Annual precipitation (mm)	Soil unit	Forest site type
Veľká Stráž (P1, P2, P3, N, 0_N, 0_C)	6	1995–2020	42–67	48°34'38.0'N 19°05'17.0'E	360	7.5	700	Haplic Cambisol	fertile beech oakwoods
Nováčany (I, II, 0)	8	1984–2019	58–93	48°40'17.0'N 21°02'05.0'E	300	7.6	750	Haplic Luvisol	fresh oak beechwoods

P1 – selection of 160 target trees per ha and their release by removing one competitive tree; P2 – selection of 160 target trees per ha and their release by removing two competitive individual trees; P3 – selection of 160 target trees per ha and their release by removing three competitive individual trees; N – the method of promising trees (1 161 trees per ha) and their release according to silvicultural requirements; since the stand age of 62 years the method of target trees (147 trees per ha) was applied; 0_N – control plot with selection of 1 074 promising trees; since the stand age of 62 years the method of target trees (187 trees per ha) was applied; 0_C – control plot with selection of 160 target trees per ha; I – plot with moderate free crown thinning; II – plot with heavy crown thinning; 0 – control plot (no thinning)

https://doi.org/10.17221/2/2026-JFS

the establishment of this LTP, the method of target trees with different intensity of release of target tree crowns was applied (160 trees·ha^{-1}), and plot N, where the method of promising trees was implemented (1 161 trees·ha^{-1} at the beginning of the research at the age of 19 years, later from the age of 62 years it was changed to the method of target trees). The area of these subplots is 0.15 ha. The other two plots are control plots (without interventions) with an area of 0.075 ha, where 1 074 promising trees (Plot 0_N), or 160 target trees (Plot 0_C) were marked.

At the time of establishing the LTP at the age of 19 years, the following research programme was defined:

– P1 – marking of target trees (160 trees·ha^{-1}) and their release by removing one competing crown-level tree;
– P2 – marking of target trees (160 trees·ha^{-1}) and their release by removing two competing trees from the stand level;
– P3 – marking of target trees (160 trees·ha^{-1}) and their release by removing three competing trees from the stand level;
– N – marking of promising trees (1 161 trees·ha^{-1}) and their release as needed; the target tree method has been implemented from the age of 62 years;
– 0_N – control plot with marking of promising trees (1 074 trees·ha^{-1}); from the age of 62 years, the target tree method has been implemented with marking of 187 target trees per ha;
– 0_C – control plot with marking of 160 target trees per ha.

Historically, on the Veľká Stráž LTP, the first measurement was carried out at the same time as the intervention, i.e. when the plot was established in the spring of 1973 at the age of 19 years (Baksa 1975). After 8 years (in spring 1981), the second biometric measurement, silvicultural classification, and intervention according to the original methodology were performed at the age of 27 years (Remiš 1982). Then, neither measurements nor interventions were performed. In 1994, the plots were reconstructed, and all research work on them to date was carried out according to the methodology of Štefančík (1984). The third biometric measurement was performed in 1995 at the age of 42 years, and since then, biometric measurements and interventions (free crown thinning) have been performed regularly at 5-year intervals. Since the third biometric measurement (in 1995), the research programme was modified: the number of removed competitors was no longer the indicator of the release of crowns of target and promising trees, but it was the degree of freedom of their crowns. Since 2015 (at the stand age of 62 years), the target tree method has been applied on plots where the method of promising trees was applied until then.

The second object of research was the Nováčany LTP (Table 1), which is located in eastern Slovakia. The stand originated naturally from uniform shelterwood regeneration. In 1974, when the research plots were established, the stand was 48 years old (Baksa 1975). The LTP series consists of the following three subplots (I, II, 0), each with an area of 0.21 ha:

– I – plot with moderate free crown thinning;
– II – plot with heavy crown thinning;
– 0 – control plot (no thinning).

On subplot I, the crown thinning with positive selection is performed, applying the method of target trees. At the first intervention (moderate intensity), each target tree was released on this plot by removing one 'most competitive' level or above-level individual tree. The removal of the intermediate tree was the only exception if this tree damaged the target tree crown. Only during the third intervention, the suppressed level of the stand was also intervened to the necessary extent. On the second subplot (designated as II), during the first intervention (stronger compared to Plot I), the same crown thinning with positive selection was applied using the target trees method. Here, each target tree was released by removing the two 'most competitive' level or above-level individual trees and intermediate trees. As on Plot I, the suppressed level of the stand was intervened to the necessary extent only during the 3rd and 4th interventions. The third subplot serves as the control plot, i.e. without planned interventions (designated as 0).

In the past, the Nováčany LTP series was damaged by the massive dieback of oak (Štefančík, Strmeň 2012). As a result, in 1981–1982, the forest operation carried out a weak intervention focused on health selection. Later, in 1984, in the then 58-year-old stand, the second intervention was carried out, and since then, biometric measurements have been performed with the necessary intervention at regular 5-year intervals.

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Data collection. Biometric measurements and silvicultural classification together with interventions are performed according to standard procedures (Štefančík 1984; Šmelko et al. 2003). The following parameters are measured and evaluated: diameter at breast height (*DBH*), height of trees and height of the crown base, relative height position, quality of trunk and crown, and crown size. Diameters of all numbered trees were measured with a metal calliper (Haglöf, Sweden) to the nearest 1 mm at two mutually perpendicular directions. Tree heights were measured with a Vertex hypsometer (Haglöf, Sweden) to the nearest 0.1 m, and crown widths were measured to the nearest 0.1 m.

The occurrence of shoot epicormics was assessed on all registered trees in the stand, separately for the lower part of the trunk and for the upper part of the trunk (up to the crown base) according to the 5-level classification (Figure 1).

Data processing and analyses. The height curves were equalised by the function of Michailoff (1943). The volume of the trunk was calculated according to regression equations (Petráš, Pajtík 1991).

Crown width, crown length, crown volume and basal area were derived. Based on four crown radii, the crown width (*CW*) was calculated as shown in Equation (1):

$$CW = \sum \frac{CR_{1-4}}{2} \tag{1}$$

where:
CR – crown radius.

Crown length was defined as the vertical distance from the crown base to the top of the crown. Crown volume (*CV*) was calculated according to Assmann (1968) for broadleaved tree species, see Equation (2):

$$CV = \frac{\pi}{8} b^2 l \tag{2}$$

where:
b – crown width (*CW*);
l – crown length (*CL*).

The background material was processed by usual biometric and statistical methods in accordance with standard methodologies (Scheer, Sedmák 2014; Šmelko et al. 2003). The relative proportions of individual categories of epicormics (1 to 5) were calculated separately for the lower and upper parts of the trunk. To calculate the basic statistical characteristics of other quantitative parameters, the programs Excel and QC Expert (Version 3.3, 2013) were used (Kupka 2013), and the correlation and regression analysis were applied to determine the relationships between the observed quantitative characteristics.

RESULTS

Quantitative production. Comparison of stand quantitative parameters (Table 2) showed higher density on all plots of the Veľká Stráž LTP at the age of 67 years (1 040 to 1 400 trees·ha^{-1} on plots with tending, or 1 547 and 1 733 trees·ha^{-1} on control plots). At the Nováčany LTP (at the age of 68 years), it was 862 and 1 158 trees·ha^{-1} on plots with tending and 1 005 trees·ha^{-1} on the control plot. Higher values of the basal area, ranging from 30.2 m^2·ha^{-1}

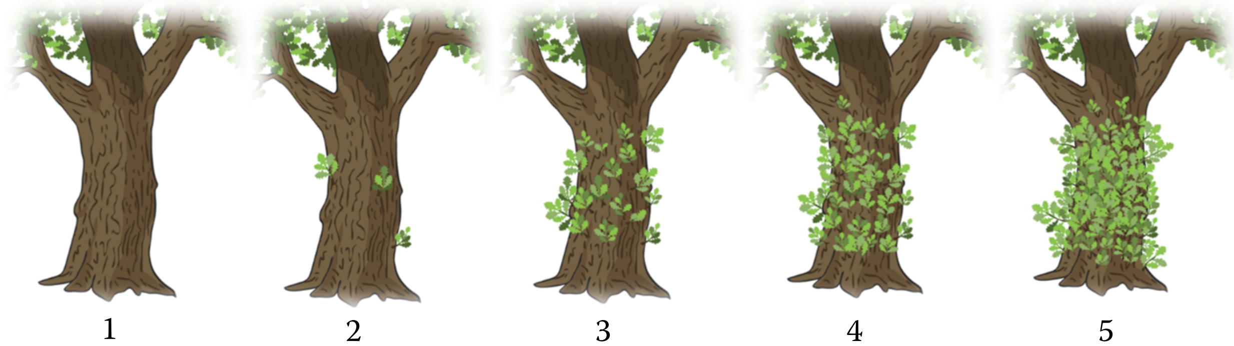

Figure 1. Occurrence classification of epicormics in the oak stands

1 – clean trunk (without epicormics); 2 – sporadic occurrence of epicormics on the evaluated part of the trunk; 3 – occurrence of epicormics on 50% of the evaluated part of the trunk; 4 – occurrence of epicormics on 75% of the evaluated part of the trunk; 5 – occurrence of epicormics on the whole evaluated part of the trunk

https://doi.org/10.17221/2/2026-JFS

Table 2. Development of mensuration characteristics

Plot	Subplot	Age (years)	Number of trees (tree·ha^{-1})	Basal area (m^2·ha^{-1})	Stand volume (m^3·ha^{-1})	*DBH* (cm)	Height (m)
Veľká Stráž	P1	62	1 706	33.3	326	15.8	19.1
		67	1 260	31.8	343	17.9	20.9
	P2	62	1 493	33.8	340	16.9	19.4
		67	1 147	33.2	363	19.2	21.3
	P3	62	1 360	30.3	303	16.9	19.5
		67	1 040	30.2	332	19.2	21.4
	N	62	1 813	33.5	322	15.4	18.2
		67	1 400	32.8	348	17.3	20.2
	0_C	62	1 947	40.6	406	16.3	19.8
		67	1 547	40.7	445	18.3	21.4
	0_N	62	1 906	42.6	427	16.9	19.8
		67	1 733	45.2	484	18.2	21.0
Nováčany	I	63	1 491	30.0	327	16.0	22.1
		68	1 158	28.3	312	17.6	21.5
	II	63	1 186	29.1	322	17.7	22.2
		68	862	26.9	305	19.9	21.9
	0	63	1 091	29.0	317	18.4	21.7
		68	1 005	30.9	353	19.8	22.3

DBH – mean diameter at breast height

to 33.2 m^2·ha^{-1} on plots with tending and from 40.7 m^2·ha^{-1} to 45.2 m^2·ha^{-1} on control plots, were also found on the Veľká Stráž LTP compared to the Nováčany LTP. For the stand volume, it was from 332 m^3·ha^{-1} to 363 m^3·ha^{-1} on plots with tending and 445 m^3·ha^{-1} and 484 m^3·ha^{-1} on control plots. The values of 26.9 m^2·ha^{-1} and 28.3 m^2·ha^{-1}, or 30.9 m^2·ha^{-1} for the basal area and 305 m^3·ha^{-1} and 312 m^3·ha^{-1}, or 353 m^3·ha^{-1} for the stand volume were found for the Nováčany LTP.

Occurrence of epicormics. In particular, the occurrence of epicormics on the lower and upper parts of the trunk was examined (Figures 2, 3). The occurrence of epicormics in both localities was always significantly higher in the upper part of the trunk compared to the lower one. At the Nováčany LTP, at the age of 68 years, the proportion of trunks without epicormics decreased compared to the previous evaluation at the age of 63 years. While at this age the upper part of the trunk had the highest proportion in Category 2 (sporadic occurrence of epicormics), at the age of 68 years, Category 3 (epicormics on 50% of the evaluated part of the trunk) was already prevalent on plots with tending.

In both years compared, the Veľká Stráž LTP had the highest proportion of trunks without epicormics in the lower part of the trunk, namely on plots N and 0_N, where the promising trees method was applied for almost the entire period. With the exception of plot P2, the upper part of the trunk was classified in Category 2 of evaluation (sporadic occurrence) at the age of 62 years. At the age of 67 years, in addition to this plot, Category 3 of occurrence prevailed on both control plots (0_N and 0_C) as well.

At the Nováčany LTP, the development of the epicormic occurrence confirmed the highest proportion in Category 1 (clean trunk without epicormics) on all plots on the lower part of the trunk over a period of 35 years (Figure 3). Their proportion was always higher on the control plot than on plots with tending, with the exception of the evaluation at the age of 63 years. Consequently, the sporadic occurrence of epicormics (Category 2) reached lower values on the control plot compared to the plots with applied thinning. Regarding the upper part of the trunks, the development of the proportion of epicormics was different. On the control plot, the highest proportion belonged to Categories 2 and 3

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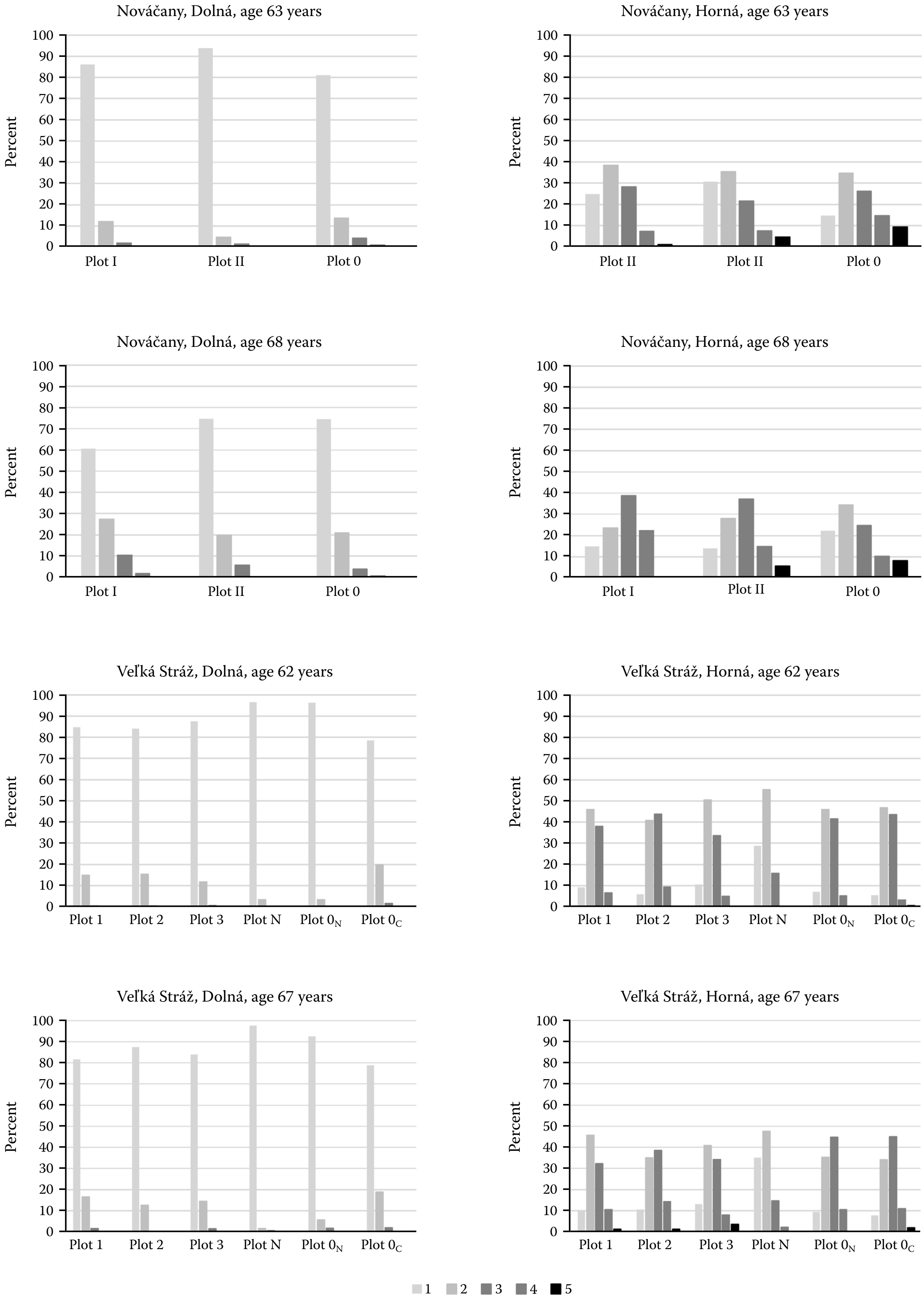

Figure 2. Proportion of epicormics (%) in each category of their occurrence according to their position on the trunk

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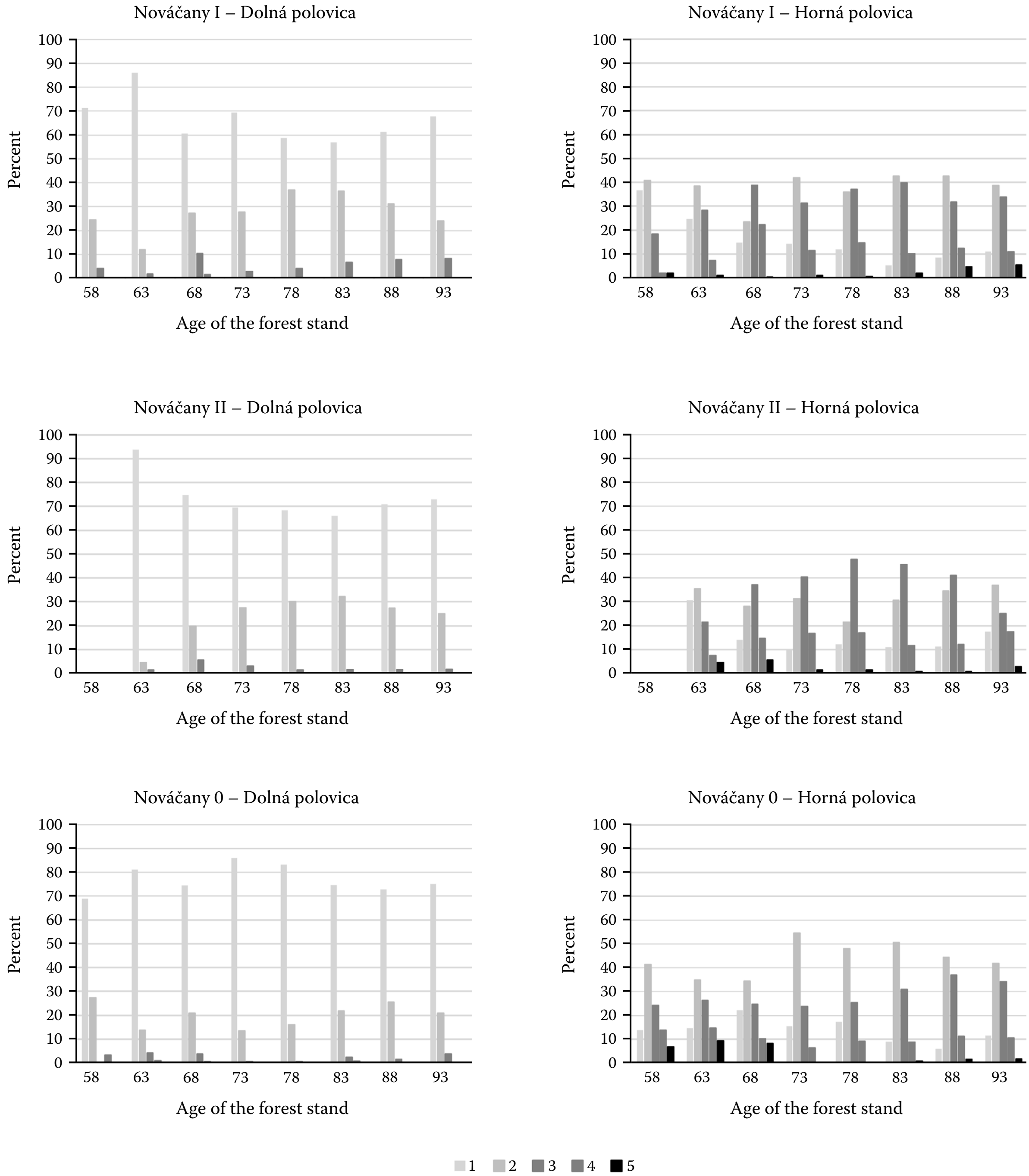

Figure 3. Development of the proportion of epicormics (%) on the Nováčany long-term research plot (LTP) over 35 years

for the entire monitored period. Plot II (heavier thinning) had the highest proportion in Category 3 (epicormics on 50% of the evaluated part of the trunk), with the exception of the first (at the age of 63 years) and the last evaluation after 30 years. The development of the proportion of epicormics on Plot I (moderate thinning) was similar to that of the control plot.

Epicormics versus selected quantitative tree parameters. It was investigated whether some quantitative parameters of the tree (*DBH*, crown width, crown volume) influence the proportion of epicormics in the lower and especially in the upper part of the trunk. Using the correlation analysis, a very weak to moderately strong relationship between the occurrence of epicormics and the three quan-

https://doi.org/10.17221/2/2026-JFS

titative parameters mentioned above was found. In total, in determining all correlations, the correlation coefficient ranged from r = 0.024 to 0.458 for the Nováčany LTP at the age of 63 years, and from r = 0.078 to 0.461 at the age of 68 years. In most cases, the correlation coefficient was higher in detecting the three relations in the lower part of the trunk compared to the upper part. The strongest correlation was found in the relationship between epicormics and *DBH* (r = 0.187–0.461). A moderately strong correlation was found between epicormics and crown width (r = 0.078–0.409) and crown volume (r = 0.024–0.369). Regarding the impact of tending, in both years, higher correlation coefficients for the three monitored relationships were observed in plots with tending compared with the control plot.

On the Veľká Stráž LTP, the correlation coefficient for all dependences ranged from r = 0.041 to 0.546 at the age of 62 years and from r = 0.104 to 0.660 at the age of 67 years. Unlike the Nováčany LTP, the correlation coefficient here was always higher in the upper part of the trunk. On the control plots, in both monitored years, the strongest correlations were found between the crown width and epicormics (r = 0.140 to 0.548) or between *DBH* and epicormics (r = 0.102 to 0.660). On plots with tending, the correlation coefficient ranged from r = 0.104 to 0.546 in the evaluation of all three relations, and on the control plots, it ranged from r = 0.041 to 0.660.

DISCUSSION

The occurrence of epicormics was always higher in the upper part of the trunk compared to the lower one in both localities (regardless of the management method). Similarly, McDonald and Ritchie (1994) found that the number of epicormics increased from the bottom of the trunk upwards. The upper part of the trunk seems more responsive to thinning because more epicormic shoots occur there than in the lower part. However, the occurrence of epicormics varied with regard to the location. On the Nováčany LTP, which was affected by an epiphytotic of massive oak dieback in the past, the highest proportion of individual oak trees without epicormics on the lower part of the trunk was on the plot with the lowest density (862 trees·ha^{-1}). On the other hand, at the Veľká Stráž LTP, where the massive oak dieback did not occur, the situation was the opposite. The highest proportion of the lower parts of trunks without epicormics was on the plots with the highest number of trees (Plots N and 0_N). In addition, these two plots have the highest proportion of suppressed individual trees (especially hornbeams), which appear to prevent the formation of epicormics. Significance of the suppressed component of the stand or the higher representation of hornbeam and nurse species in the suppressed level was confirmed by several authors in the past (Chroust 1997; Slávik, Štefančík 2015). The relationship between the occurrence of epicormic shoots and three initial densities in a 20-year-old durmast oak plantation was evaluated by Colin et al. (2008). They found the longest epicormic shoots at the density of 1 333 and 2 667 trees per ha, while their average length was significantly smaller at the density of 5 333 trees per ha.

In the upper part of the trunk, the proportion of epicormics on the intervened plots changed between the two evaluated periods on the Nováčany LTP. While at the age of 63 years, the proportion of individual trees with sporadic occurrence of epicormics predominated, at the age of 68, the highest occurrence was in Category 3 (occurrence on 50% of the trunk length). The control plot maintained the same trend in both evaluations. On the Veľká Stráž LTP, the plots with thinning maintained the same trend of Category 1 and 2 of epicormic occurrence, which means no epicormics or sporadic occurrence of shoots. However, on control plots, the higher proportion of individual trees with sporadic epicormic occurrence at the age of 62 years decreased to a lower proportion 5 years later. These findings suggest a different effect of thinning on the occurrence of epicormics in a relatively healthy forest stand compared to a stand previously affected by the massive oak dieback.

In connection with the forest stand density, the intensity of thinning is probably also important. Pretzsch and Utschig (1995) reported that the extent of epicormics increased after light and heavy crown thinning in the durmast oak stand. At the age of 108 years, epicormics occurred on 37% to 41% of the trunk length, which corresponds approximately to Categories 1 and 2 of our classification. At the same time, it corresponds to our results obtained for the upper part of the trunk in both localities, in terms of the intervention intensity. In the mentioned years, it ranged from 0.4% to 7.3% of the basal area on the Veľká Stráž LTP, or from

https://doi.org/10.17221/2/2026-JFS

3.4% to 12.8% on the Nováčany LTP. For deciduous tree species, Howell and Nix (2002) found that, depending on the intensity of thinning, the number of epicormics could increase 2 to 3 times compared to the control plot results. On the other hand, some authors stated that thinning does not increase the number of epicormic shoots, but mainly their size (Hibbs et al. 1989).

In addition to the thinning and stand density, it can be assumed that the occurrence of epicormics is also affected by pruning. Buresti et al. (2000) conducted research on the pedunculate oak (*Quercus robur L.*) plantation, where, after 4 years (at the age of 22 years) and the second thinning, 257 trees per ha remained with pruned trunks to a height of 5 m. Although heavy thinning was performed, the occurrence of epicormic shoots appeared to be rather a consequence of pruning than thinning. The same opinion was published by Attocchi (2013), who stated that pruning led to an overall increase in the formation of new epicormics. More epicormics were in the lower part of the trunk (at a height of 0 to 3 m) than in the upper part (3 to 6 m). The number of new epicormic shoots increased with increasing stand density, which was also confirmed in our experiment, although without pruning. In contrast, McDonald and Ritchie (1994) found in a 60-year-old Kellogg oak stand (*Quercus kelloggii* Newb.) in California that the number of epicormics increased with decreasing density. The age of the stand in which pruning is performed is also important. According to Sardino (ex Attocchi 2013), the decisive phase for this purpose is the small-pole stage (mean *DBH* from 10 cm to 20 cm) after the first thinning at a height of 12 m to 18 m. In forest stands where the occurrence of epicormics was evaluated, no pruning was performed in combination with thinning. So, it is questionable how this would be reflected in the forest stand damaged by the massive dieback of oak compared to a healthy stand. Early and heavy thinning, combined with high pruning at regular intervals, can help to shorten the rotation period for pedunculate oak without reducing the quality of wood because of the wider annual rings (Attocchi 2013). Likewise, studies comparing oak grown on forest and post-agricultural land indicate that differences in site history may affect wood structure and selected mechanical properties, while overall timber quality remains largely comparable, emphasising the role of site conditions alongside silvicultural practices (Tomczak et al. 2024).

One of the goals of our research was to determine the relationship between epicormic formation and selected quantitative characteristics of the tree (*DBH*, crown width and crown volume). These parameters were chosen because it was assumed that the occurrence of epicormics in oak is mainly influenced by crown size (width and volume). It also influences a different amount of light that penetrates through the canopy and can be regulated by thinning (Chroust 1997). Similarly, McDonald and Ritchie (1994) concluded that vital trees had better-developed crowns and produced fewer epicormics. They stated that sudden exposure of trunks to increased light levels almost always leads to the formation of epicormics and a decrease in trunk quality. In our experiment, the highest correlation coefficient between epicormics and *DBH* was found on plots with tending. There were differences between the plots in the relationship between epicormics and crown width and crown volume. This is related to different development due to the massive oak dieback in the past and the resulting changes in density. This is related not only to the intensity of thinning, but also to the intensity of self-thinning, which occurred on plots with thinning on the Nováčany LTP (2.7% to 8.1%) and Veľká Stráž LTP (2.7% to 6.1%). McDonald and Ritchie (1994) reported that the larger the basal area, the fewer epicormics occurred in stands of varying density (Kellogg oak) in California at the age of 60 years.

From the perspective of growing oak stands, appropriate and timely selection of individual trees without epicormics, or trees which should be target trees with the lowest possible number of epicormics, especially suppressed buds, is important (Morisset et al. 2012a, b). According to these authors, this should be done at the first thinning when the stand reaches the height of 12 m to 14 m. Trees with a small cluster of epicormics or epicormics with the potential in youth, in combination with massive annual height increment, must be selected to create a population of target trees. Numerous experiments with the tending of oak stands by the method of target trees recommend their selection in the growth phase from young stands (Sloup et al. 2019) to small-pole stands according to certain criteria (Korpeľ 1984; Štefančík 1991). To achieve a trunk without epicormics at least

https://doi.org/10.17221/2/2026-JFS

4 m to 6 m in length it is recommended to use light but frequent crown thinning to release target trees, maintain the suppressed level that allows lateral widening and at the same time shading the branches of free parts of the trunk and appropriate selection of target trees around the age of 30 years (Colin et al. 2010).

In our experiment in a healthy stand of the Veľká Stráž LTP, target trees were selected in most cases at the same age as reported by these authors. In terms of quantitative and qualitative production, the best results were obtained on plots managed by the target tree method from the beginning. Here, the target trees were released less intensively (18.9% and 22% by basal area) in the first two interventions. Conversely, the most epicormics were observed on the plot with more intensive initial interventions.

CONCLUSION

The differences in the development of the two oak stands manifested themselves in selected quantitative characteristics of the stands. The number of trees, basal area and the stand volume were always lower in the locality affected by the massive dieback of oak in the past compared to the locality without this disease (healthy stands). The occurrence of epicormics in both localities was always significantly higher in the upper part of the trunk compared to the lower one. In both localities, over the 5 monitored years, the proportion of epicormics in the upper part of the trunk increased on plots with thinning and on control plots. The development of the proportion of epicormics in the lower part of the trunk in the locality with massive dieback of oak over a longer period of 35 years confirmed more favourable values on the control plots compared to the thinned plots. When evaluating the upper part of the trunks, the development of the proportion of epicormics was different depending on the management or the intensity of tending. There was a very weak to moderately strong relation between epicormics and selected quantitative characteristics of the tree (*DBH*, crown width and volume). A closer relationship was in the lower part of the trunk and on plots with tending, where the massive dieback of oak occurred. In healthy oak stands, it was the opposite. There was a higher dependence in the upper part of the trunk and on the control plots. It follows from the above that the occurrence of epicormics in oak stands is influenced, among other factors, not only by different methods of management, but also by the health condition. A limitation of this study is that it was conducted on only two oak stands with different health histories, which may constrain the generalisation of the findings to other sites or forest types with differing stand conditions, structures, or management regimes.

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REFERENCES

Ábri T., Keserű Z., Honfy V., Rédei K.M. (2025): Diameter growth performance of northern red oak (*Quercus rubra* L.) in northeastern Hungary. Journal of Forest Science, 71: 384–392.

Attocchi G. (2013): Effects of pruning and stand density on the production of new epicormic shoots in young stands of pedunculate oak (*Quercus robur* L.). Annals of Forest Science, 70: 663–673.

Attocchi G. (2015): Silviculture of oak for high-quality wood production. Acta Universitatis Agriculturae Sueciae, 39: 1–86.

Baksa L. (1970): Produkčný cieľ v dubinách. Bratislava, Príroda: 148. (in Slovak)

Baksa L. (1975): Výchova dubových porastov. (Záverečná správa). Zvolen, VÚLH: 112. (in Slovak)

Bárdos B., Nahóczki L., Molnár D., Frank N., Köveskuti Z., Folcz Á. (2015): Investigation of epicormic shoot growth of sessile oak in shelterwood cutting stands. Erdészettudományi Közlemények, 5: 71–83.

Bobinac M., Andrašev S. (2001): Effects of silvicultural treatments in remediating the devitalisation consequences in a young pedunculate oak stand. Glasnik Šumarskog Fakulteta, Univerzitet u Beogradu, 84: 17–32.

Buresti E., de Meo I., Pelleri F. (2000): Criteri e risultati di un diradamento in un impianto di arboricltura da legno di farnia (*Quercus robur* L.). Annali dell Istituto Sperimentale per la Selvicoltura, 29: 29–40. (in Italian)

Čapek M., Brutovský D., Finďo S., Grék J., Halaj J., Hešková A., Leontovič R. (1985): Hromadné hynutie dubov na Slovensku. Bratislava, Príroda: 112. (in Slovak)

Černý J., Špulák O., Kománek M., Žižková E., Sýkora P. (2024): Sessile oak [*Quercus petraea* (Matt.) Liebl.] and its adaptation strategies in the context of global climate change: A review. Central European Forestry Journal, 70: 77–94.

https://doi.org/10.17221/2/2026-JFS

Chroust L. (1997): Ekologie výchovy lesních porostů. Opočno, Forestry and Game Management Research Institute: 277. (in Czech)

Chroust L. (2007): Quality selection in young oak stands. Journal of Forest Science, 53: 210–221.

Colin F., Robert N., Druelle J.L., Fontaine F. (2008): Initial spacing has little influence on transient epicormic shoots in a 20-year-old sessile oak plantation. Annals of Forest Science, 65: 508.

Colin F., Mechergui R., Dhôte J.F., Fontaine F. (2010): Epicormic ontogeny on *Quercus petraea* trunks and thinning effects quantified with the epicormic composition. Annals of Forest Science, 67: 813.

Cukor J., Linhart L., Vacek Z., Baláš M., Linda R. (2017a): The effects of Alginite fertilization on selected tree species seedlings performance on afforested agricultural lands. Central European Forestry Journal, 63: 48–56.

Cukor J., Vacek Z., Linda R., Remeš J., Bílek L., Sharma R.P., Baláš M., Kupka I. (2017b): Effect of mineral eco-fertilizer on growth and mortality of young afforestations. Austrian Journal of Forest Science, 134: 367–385.

Cukor J., Vacek Z., Vacek S., Linda R., Podrázský V. (2022): Biomass productivity, forest stability, carbon balance, and soil transformation of agricultural land afforestation: A case study of suitability of native tree species in the submontane zone in Czechia. Catena, 210: 105893.

Dušek D., Slodičák M., Novák J. (2011): Vliv pozitivního a negativního výběru uplatněného při prvních výchovných zásazích na růst a vývoj dubové mlaziny. Zprávy lesnického výzkumu, 56: 125–129. (in Czech)

Eaton E., Caudullo G., Oliveira S., De Rigo D. (2016): *Quercus robur* and *Quercus petraea* in Europe: Distribution, habitat, usage and threats. In: San-Miguel-Ayanz J., de Rigo D., Caudullo G., Houston Durrant T., Mauri A. (eds): European Atlas of Forest Tree Species. Luxembourg, Publication Office of the European Union: 60–163.

Eisenhauer D.R. (1989): Posúdenie vývoja stability vybraných dubových ekosystémov. Acta Facultatis Forestalis Zvolen, 31: 143–157. (in Slovak)

Fürst C., Vacik H., Lorz C., Makeschin F., Podrázský V., Janeček V. (2007): Meeting the challenges of process-oriented forest management. Forest Ecology and Management, 248: 1–5.

Gaertig T.H., Schack-Kirschner H., Hildebrang E.E., Wilpert K. (2002): The impact of soil aeration on oak decline in southwestern Germany. Forest Ecology and Management, 159: 15–25.

Gubka K., Sklenár P. (2006). Porovnanie niektorých znakov štruktúry porastov duba červeného (*Quercus rubra* L.) a duba zimného [*Quercus petraea* (Mattusch) Liebl.]. Acta Facultatis Forestalis Zvolen, 48: 183–196.

Harmer R. (1990): The timing of canopy and epicormic shoot growth in *Quercus robur* L. Forestry, 63: 279–283.

Hochbichler E. (1993): Methods of oak silviculture in Austria. Annales des Sciences Forestières, 50: 583–591.

Hurt V. (2012): Produkční potenciál a stabilita smíšeného dubohabrového porostu na eutrofním stanovišti ve Ždánickém lese. In: Saniga M., Kucbel S., Jaloviar P. (eds.): Silviculture in Central Europe. Zvolen, Technical University in Zvolen: 153–163. (in Czech)

Jakucs P. (1988): Ecological approach to forest decay in Hungary. Ambio, 17: 267–274.

Kadavý J., Adamec Z., Uherková B., Kneifl M., Knott R., Kučera A., Friedl M., Dařenová E., Skládanka J., Drápela K. (2019): Growth response of sessile oak and European hornbeam to traditional coppice-with-standards management. Forests, 10: 515.

Keenan R.J. (2015): Climate change impacts and adaptation in forest management: A review. Annals of Forest Science, 72: 145–167.

Kerr G. (1996): The effect of heavy or 'free growth' thinning on oak (*Quercus petraea* and *Q. robur*). Forestry, 69: 303–317.

Kerr G., Harmer R. (2001): Production of epicormic shoots on oak (*Quercus robur*): Effects of frequency and time of pruning. Forestry, 74: 467–477.

Korpeľ Š. (1981): Výchova zmiešaných dubových porastov a jej vplyv na štruktúru a produkciu. Vedecké práce Výskumného ústavu lesného hospodárstva vo Zvolene, 31: 65–109. (in Slovak)

Korpeľ Š. (1984): Racionalizácia výchovy dubových húštin neceloplošnou čistkou vo vlhkých bukových dúbravách. Acta Facultatis Forestalis, 26: 79–97. (in Slovak)

Krahl-Urban J. (1959): Die Eichen. Hamburg, Verlag Paul Parey: 288. (in German)

Kupka K. (2013): QC.Expert 3.1. Uživatelský manuál. Pardubice, TryloByte: 266. (in Czech)

Leibundgut H. (1945): Über die waldbauliche Behandlung der Eiche. Schweizerische Zeitschrift für Forstwesen, 1: 49–58. (in German)

Leontovyč R., Patočka J., Grék J. (1987): Výskyt a význam hromadného hynutia dubov vo svete a na Slovensku. Vedecké práce Výskumného ústavu lesného hospodárstva vo Zvolene, 36: 13–32. (in Slovak)

Lorrain-Smith R. (1972): Economic problems of growing hardwoods in Great Britain. Arboricultural Journal, 3: 164–169.

Malaisse F., Burgeon D., Degreef J., Deom B., Van Doren B. (1993): Le dépérissement des chênes indigènes en Europe occidentale. Note 1. – Symptômes de perte de vitalité. Belgium Journal of Botany, 126: 191–205. (in French)

MARD SR (2025): Green Report Brochure 2024. Bratislava, Ministry of Agriculture and Rural Development of the Slovak Republic: 74.

https://doi.org/10.17221/2/2026-JFS

McDonald P., Ritchie M.W. (1994): Epicormic branching of California black oak: Effect of stand and tree characteristics. Northwest Science, 68: 6–10.

Michailoff I. (1943): Zahlenmässiges Verfahren für die Ausführung der Bestandeshöhenkurven. Forstwissenschaftkiches Centralblatt und Tharandter Forstliches Jahrbuch, 6: 273–279. (in German)

Miltner S., Podrázský V., Baláš M., Kupka I. (2017): Vliv dubu červeného (*Quercus rubra* L.) na lesní stanoviště. Zprávy lesnického výzkumu, 62: 109–115. (in Czech)

Mölder A., Meyer P., Nagel R.V. (2019): Integrative management to sustain biodiversity and ecological continuity in Central European temperate oak (*Quercus robur*, *Q. petraea*) forests: An overview. Forest Ecology and Management, 437: 324–339.

Morisset J.B., Mothe F., Chopard B., François D., Fontaine F., Colin F. (2012a): Does past emergence of epicormic shoots control current composition of epicormic types? Annals of Forest Science, 69: 139–152.

Morisset J.B., Mothe F., Colin F. (2012b): Observation of *Quercus petraea* epicormic with X-ray CT reveals strong pith-to-bark correlations: Silvicultural and ecological implications. Forest Ecology and Management, 278: 127–137.

Nicolescu V.N., Vor T., Brus R., Dodan M., Peric S., Podrázský V., Andrašev S., Tsavkov E., Ayan S., Yucedag C., Trajkov P., Kolevska D.D., Buzatu-Goanta C., Pstor M., Macejovský V., Modranský J., Klisz M., Gil W., Lavnyy V., Madsen P., La Porta N., Brtlett D. (2025): Management of sessile oak [*Quercus petraea* (Mat.) Liebl.], a major forest species in Europe. Journal of Forestry Research, 36: 78.

Petráš R., Pajtík J. (1991): Sústava česko-slovenských objemových tabuliek drevín. Lesnícky časopis, 37: 49–56. (in Slovak)

Podrázský V., Kupka I. (2024): Vliv dubu červeného (*Quercus rubra* L.) na stav lesních půd – Případová studie. Zprávy lesnického výzkumu, 69: 143–148. (in Czech)

Poleno Z., Vacek S., Podrázský V., Remeš J., Štefančík I., Mikeska M., Kobliha J., Kupka I., Malík V., Turčáni M., Dvořák J., Zatloukal V., Bílek L., Baláš M., Simon J. (2009): Pěstování lesů III. Praktické postupy pěstování lesů. Kostelec nad Černými lesy, Lesnická práce: 952. (in Czech)

Pretzsch H., Utschig H. (1995): Die Eichen-versuchsflächen im Forstamt Elmstein-Nord. Allgemeine Forst Zeitschrift, 50: 67–71. (in German)

Pretzsch H., Steckel M., Heym M., Biber P., Ammer C., Ehbrecht M., Bielak K., Bravo F., Ordóñez C., Collet C., Vast F., Drössler L., Brazaitis G., Godvod K., Jansons A., de-Dios-García J., Löf M., Aldea J., Korboulewsky N., Reventlow D.O.J., Nothdurft A., Engel M., Pach M., Skrzyszewski J., Pardos M., Ponette Q., Sitko R., Fabrika M., Svoboda M., Černý J., Wolff B., Ruíz-Peinado R., del Río M. (2020): Stand growth and structure of mixed-species and monospecific stands of Scots pine (*Pinus sylvestris* L.) and oak [*Q. robur* L., *Quercus petraea* (Matt.) Liebl.] analysed along a productivity gradient through Europe. European Journal of Forest Research, 139: 349–367.

Račko J., Šmelko Š., Scheer Ľ., Pánek F. (1987): Využitie leteckej snímky pri výskume a inventarizácii porastov postihnutých hromadným hynutím duba. Vedecké práce Výskumného ústavu lesného hospodárstva vo Zvolene, 36: 243–254. (in Slovak)

Remiš J. (1982): Včasnosť ako racionalizačný aspekt určenia cieľových stromov v dubinách. Zprávy lesnického výzkumu, 27: 20–23. (in Slovak)

Scheer Ľ., Sedmák R. (2014): Biometria. Zvolen, Technical University in Zvolen: 310. (in Slovak)

Schütz J.P. (1993): High-quality oak silviculture in Switzerland – Concepts of education and production in the marginal range of European oak. Annals of Forest Science, 50: 553–562.

Seidl R., Thom D., Kautz M., Martin-Benito D., Peltoniemi M., Vacchiano G., Wild J., Ascoli D., Petr M., Honkaniemi J., Lexer M.J., Trotsiuk V., Mairota P., Svoboda M., Fabrika M., Nagel T., Reyer C.P. (2017): Forest disturbances under climate change. Nature Climate Change, 7: 395–402.

Šimková M., Vacek S., Šimůnek V., Vacek Z., Cukor J., Hájek V., Bílek L., Prokůpková A., Štefančík I., Sitková Z., Lukáčik I. (2023): Turkey oak (*Quercus cerris* L.) resilience to climate change: Insights from coppice forests in Southern and Central Europe. Forests, 14: 2403.

Siwecki R., Ufnalski K. (1998): Review of oak stand decline with special reference to the role of drought in Poland. European Journal of Forest Pathology, 28: 99–112.

Slávik M., Štefančík I. (2015): Comparison of selected qualitative characteristics of stem in oak stands under varying effects of auxiliary tree species. Lesnícky časopis – Forestry Journal, 61: 31–36. (in Czech)

Slodičák M., Novák J., Dušek D. (2009): Thinning of oak stands – Results of 12-year study in oak thicket. In: Štefančík I., Kamenský M. (eds): Pestovanie lesa ako nástroj cieľavedomého využívania potenciálu lesov. Zvolen, NLC: 184–189.

Sloup M., Slodičák M., Lehnerová L., Lehečka J. (2019): Vliv prvních výchovných zásahů na růst a vývoj mlaziny dubu zimního. Lesnická Práce, 98: 38–42. (in Czech)

Šmelko Š., Scheer Ľ., Petráš R., Ďurský J., Fabrika M. (2003): Meranie lesa a dreva. Zvolen, ÚVVPLVH: 240. (in Slovak)

Stavi I., Thevs N., Welp M., Zdruli P. (2022): Provisioning ecosystem services related with oak (*Quercus*) systems: A review of challenges and opportunities. Agroforestry Systems, 96: 293–313.

https://doi.org/10.17221/2/2026-JFS

Štefančík L. (1984): Úrovňová voľná prebierka – Metóda biologickej intenzifikácie a racionalizácie selekčnej výchovy bukových porastov. Vedecké práce Výskumného ústavu lesného hospodárstva vo Zvolene, 34: 69–112. (in Slovak)

Štefančík L. (1991): Výsledky výskumu neceloplošnej výchovy mladých dubových porastov. Vedecké práce Výskumného ústavu lesného hospodárstva vo Zvolene, 40: 169–191. (in Slovak)

Štefančík I. (2011): Výsledky výskumu neceloplošnej výchovy dubového porastu z prirodzenej obnovy. Zprávy lesnického výzkumu, 56: 255–264. (in Slovak)

Štefančík I. (2012): Growth characteristics of oak [*Quercus petraea* (Mattusch.) Liebl.] stand under different thinning regimes. Journal of Forest Science, 58: 67–78.

Štefančík I., Strmeň S. (2012): Assessment of structure, growth and development of oak stand [*Quercus petraea* (Mattusch.) Liebl.] affected by mass decay in the past. Lesnícky časopis – Forestry Journal, 58: 10–21. (in Slovak)

Thomas F.M., Blank R., Hartmann G. (2002): Abiotic and biotic factors and their interactions as causes of oak decline in Central Europe. Forest Pathology, 32: 277–307.

Tomczak K., Mania P., Cukor J., Vacek Z., Komorowicz M., Tomczak A. (2024): Wood quality of pendulate oak on post-agricultural land: A case study based on physico-mechanical and anatomical properties. Forests, 15: 1394.

Vacek Z., Vacek S., Bílek L., Král J., Ulbrichová I., Simon J., Bulušek D. (2018a): Impact of applied silvicultural systems on spatial pattern of hornbeam-oak forests. Central European Forestry Journal, 64: 33–45.

Vacek Z., Cukor J., Vacek S., Podrázský V., Rostislav L., Kovařík J. (2018b): Forest biodiversity and production potential of post-mining landscape: Opting for afforestation or leaving it to spontaneous development? Central European Forestry Journal, 64: 116–126.

Vacek S., Vacek Z., Ulbrichová I., Bulušek D., Prokůpková A., Král J., Vančura K. (2019): Biodiversity dynamics of differently managed lowland forests left to spontaneous development in Central Europe. Austrian Journal of Forest Science, 136: 249–282.

Vacek Z., Prokůpková A., Vacek S., Cukor J., Bílek L., Gallo J., Bulušek D. (2020): Silviculture as a tool to support stability and diversity of forests under climate change: Study from Krkonoše Mountains. Central European Forestry Journal, 66: 116–129.

Vacek Z., Vacek S., Cukor J. (2023): European forests under global climate change: Review of tree growth processes, crises and management strategies. Journal of Environmental Management, 332: 117353.

Vančura K., Šimková M., Vacek Z., Vacek S., Gallo J., Šimůnek V., Podrázský V., Štefančík I., Hájek V., Prokůpková A., Králíček I. (2022): Effects of environmental factors and management on dynamics of mixed calcareous forests under climate change in Central European lowlands. Dendrobiology, 87: 79–100.

Venet J. (1967): Sylviculture des forêts de chêne de tranchage. Revue Forestière Française, 19: 585–597. (in French)

Von Oheimb G., Härdtle W., Naumann P.S., Westphal C., Assmann T., Meyer H. (2008): Long-term effects of historical heathland farming on soil properties of forest ecosystems. Forest Ecology and Management, 255: 1984–1993.

Wignall T.A., Browning G., Mackenzie K.A.D. (1987): The physiology of epicormic bud emergence in pedunculate oak (*Quercus robur* L.) responses to partial notch girdling in thinned and unthinned stands. Forestry, 60: 45–56.

Wignall T.A., Browning G. (1988): The effects of stand thinning and artificial shading on epicormic bud emergence in pedunculate oak (*Quercus robur* L.). Forestry: An International Journal of Forest Research, 61: 45–59.

Zúbrik M., Kunca A., Galko J., Rell S., Vakula J., Leontovyč R., Gubka A., Nikolov H. (2019): Stojíme pre ďalšou kalamitou mníšky veľkohlavej? Les & Letokruhy, 75: 28–29. (in Slovak)

Žižková E., Kománek M., Krausková D., Černý J. (2025): Comparison of shelterwood and clear-cut regeneration methods on morphological traits of naturally regenerated sessile oak [*Quercus petraea* (Matt.) Liebl.] seedlings. Journal of Forest Science, 71: 542–554.

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