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Response of diameter and height increment to thinning in oak-hornbeam coppice in the southeastern part of the Czech Republic

B. Fedorová[1], J. Kadavý[1], Z. Adamec[1], M. Kneifl[1], R. Knott[2]

[1]*Department of Forest Management and Applied Geoinformatics, Faculty of Forestry and Wood Technology, Mendel University in Brno, Brno, Czech Republic*

[2]*Department of Silviculture, Faculty of Forestry and Wood Technology, Mendel University in Brno, Brno, Czech Republic*

ABSTRACT: The objective of this paper was to test the hypothesis that growth and soil moisture would increase after heavy thinning in seven years old oak-hornbeam coppice stand. Effects of thinning on (*i*) diameter and height increment of the remaining sprouts in polycormons, and (*ii*) soil moisture were studied one year after thinning. The experiment was carried out in the southeastern part of the Czech Republic. Thinning reduced 50% of the total stump basal area per polycormon. One to five dominant sprouts were left. Results showed that thinning significantly increased diameter increment of sessile oak (59%) and European hornbeam (61%). However, thinning did not increase height increment of sessile oak and European hornbeam. Diameter increments of sessile oak and European hornbeam were not different. Height increment of European hornbeam was 30% higher than that of sessile oak in thinned plots and 53% higher in unthinned plots. Soil moisture increased significantly in thinned plots.

Keywords: drought; European hornbeam; growth of sprouts; sessile oak; soil moisture; stump basal area

Legislation in the Czech Republic distinguishes three different silvicultural systems: high forest, coppice and coppice-with-standards. High forest is the most frequently represented silvicultural system. Nowadays, coppice or coppice-with-standards becomes increasingly a good option for small forest owners. In coppice, the owners can achieve a more balanced yield compared to high forest (Kneifl et al. 2011). Coppicing has been a traditional and old silvicultural system in the Czech Republic (Müllerová et al. 2014). Coppicing was common for centuries in most of the European lowland forests (Rackham 2010). Coppice forests produce, among other assortments, also firewood which is a renewable energy resource. Nowadays, special significance of coppices for nature conservation is acknowledged. Re-introduction of a traditional system of coppice management is the best way of maintaining valuable and attractive mixtures of herbs (Buckley 1992; Brunet et al. 1996; Konvička et al. 2006; van Calster et al. 2008; Vild et al. 2013).

In the history, no interventions were usually carried out in coppice stands before the determined period of rotation, mostly because of economic reasons. Nowadays, in the light of new findings related to global climate change, it seems reasonable to carry out thinning in coppices. It has been discovered that soil moisture increases after thinning and thus more water is available to remaining sprouts in polycormons. This topic has been studied in the Mediterranean area and several papers documented a positive impact of thinning on soil moisture (Cotillas et al.

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2009; Rodríguez-Calcerrada et al. 2011). According to the forecasts (Choat et al. 2012; Pretel 2012; IPCC 2014), drought will be a big issue in forestry.

Nowadays, coppices cover 0.7% (19,825 ha) and coppices-with-standards cover 1.9% (51,187 ha) of the total forest area of the Czech Republic. Oak and hornbeam – among the broadleaved tree species – cover 7.4% and 1.9% of the forest area of the Czech Republic, respectively (Forest Management Institute 2007). In the Mediterranean area, information about the impact of thinning on holm oak (*Quercus ilex* Linnaeus), Pyrenean oak (*Quercus pyrenaica* Willdenow), and *Quercus cerriodes* Wilk & Costa growth is available. However, information on typical, central European coppice tree species such as sessile oak (*Quercus petraea* (von Mattuschka) Liebl) and European hornbeam (*Carpinus betulus* Linnaeus) is only scarce (Šálek et al. 2014). Because of this fact, we established experimental plots in 2008, where high forest has been converted to coppice and coppice-with-standards. The plots were located in 30 and 40 years old quasi high forest (derived from coppice). The yield class of sessile oak was 24 and of European hornbeam it was 18 according to Forest Management Plan 2003–2012. The value of a yield class is the average height of the vegetation at the standard age (100 years in this country). The aim of the article is to find out whether there is a significant impact of thinning in coppice on (*i*) diameter and height increment of the remaining sprouts, and (*ii*) soil moisture.

MATERIAL AND METHODS

Study site. Our research was carried out in the territory of the Training Forest Enterprise Masaryk Forest Křtiny, Bílovice forest district, in the southeastern part of the Czech Republic (49°25'N latitude, 16°68'E longitude). The mean elevation in the study site is 328 m a.s.l., on a western slope with 5° inclination. The soil type is Cambisol on the granodiorite bedrock. The predominant forest type is nutrient-medium beech-oak stand with *Galium rotundifolium* Linnaeus (Viewegh et al. 2003). The annual mean temperature in the area is approximately 7.5°C, with annual rainfall of 550–650 mm. In the seven-year-old coppice stand, the main tree species which were studied were sessile oak and European hornbeam (associated species: European beech (*Fagus sylvatica* Linnaeus), silver birch (*Betula pendula* Roth), wild cherry (*Prunus avium* Linnaeus) and wild service tree (*Sorbus torminalis*/ Linnaeus/Crantz)).

Experimental design and field measurements. The research area has a rectangular shape (40 × 125 m). It was fenced prior to the experiment beginning and the surrounding area was classified as a protection zone. The research area is divided into eight rectangles. In the centre of each rectangle, a circular plot with a radius of 5 m was established, where quantitative and qualitative characteristics were measured. Between these circular plots is a 14 m wide buffer zone. The research plot was established in 2008 using the methodology according to Kadavý et al. (2011a). Basic overview of the circular plots is shown in Table 1.

At the beginning and at the end of the growing season 2015, diameters, heights and numbers of sprouts in polycormons were recorded.

Diameters of sprouts thicker than 1 cm were measured with a digital calliper in two directions perpendicular to each other 50 cm above the ground and then averaged. All polycormons were permanently numbered and the diameter measurement points were signed with a white horizontal line. The height of

Table 1. Basic characteristics of the research plots before thinning (standard deviation in parentheses)

No.	Thinning	Proportion in species composition* (%)		Hg (m)		Dg** (cm)		Polycormons	Sprouts	G** (m^2)
		SO	EH	SO	EH	SO	EH	(pcs·ha^{-1})		
1	no	89	11	3.4 (0.7)	4.1 (0.3)	3.5 (1.0)	3.3 (0.8)	5 856	14 894	10.2
2	no	75	17	3.1 (0.7)	3.6 (0.7)	2.9 (1.0)	2.8 (1.1)	6 747	16 549	8.7
3	yes	79	16	2.7 (0.6)	3.7 (0.7)	2.8 (1.0)	3.2 (0.5)	5 856	13 494	6.7
4	yes	75	17	2.8 (0.7)	3.2 (0.7)	2.8 (1.0)	2.2 (0.7)	7 893	15 658	6.8
5	no	10	89	4.7 (0.7)	4.6 (0.8)	6.2 (1.0)	3.9 (1.0)	2 801	10 693	8.8
6	no	12	88	4.0 (0.6)	4.8 (0.7)	4.1 (0.9)	3.8 (0.6)	2 291	14 512	10.1
7	yes	11	87	4.3 (0.5)	4.4 (0.8)	4.3 (0.8)	3.6 (1.1)	3 819	13 876	10.0
8	yes	49	50	4.1 (0.6)	4.3 (0.8)	4.4 (1.3)	3.4 (0.7)	3 819	16 167	11.9

SO – sessile oak, EH – European hornbeam, Hg – mean height, Dg – quadratic mean diameter, G – basal area per ha, *calculated from G, **at 0.5 m a.g.l.

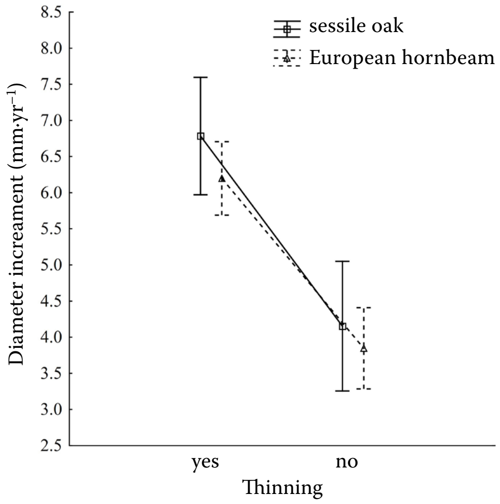

Fig. 1. Mean values of diameter increment (with 95% confidence intervals) of sessile oak and European hornbeam for thinned and unthinned plots

the longest sprout in each polycormon was measured with a telescopic rod.

Four of the eight rectangular subplots were thinned in the winter 2014/2015. Thinning was done with a hand saw at the ground level by a 50% basal area reduction in each polycormon. The reduction was carried out by leaving 1–3 dominant sprouts per stump for sessile oaks and 1–5 dominant sprouts per stump for European hornbeam polycormons. A standard climatic station (EMS Brno, Czech Republic) was set up in an open place on the experimental site in 2014. Air temperature and precipitation were measured and stored in a data logger in one-hour interval.

A soil pit was dug in May 2015, all soil horizons were classified and described. Important and practical information we derived from the soil pit was a depth of the rooting zone. It reached to 40 cm below the ground. This information was necessary to set the depths of soil moisture sensors.

Soil moisture was monitored from June to November 2015 using a PR2 Profile Probe (Delta-T Devices, Ltd., Cambridge, UK) and SM300 Soil Moisture Sensor with HH2 Moisture Meter – Readout Unit (Delta-T Devices, Ltd., Cambridge, UK). Twelve 40 cm long probes were permanently installed by soil augers into the soil on four circular plots where thinning was carried out, and the parts without interventions. Volumetric soil moisture content was measured every three weeks at 5 cm with SM300 Soil Moisture Sensor and at 10, 20, 30 and 40 cm with PR2 Profile Probe.

Statistical analyses. The response of diameter and height increments to different treatments in oak-hornbeam coppice was analysed by a two-sample *t*-test. The same method was used to find out whether treatments affected the soil moisture. Comparison of diameter and height increments between sessile oak and European hornbeam was also carried out. This was tested for thinned and unthinned plots separately. All tests were done with the significance level $\alpha = 0.05$, thus the confidence of results was 95%. All analyses were done in STATISTICA (Version 12, 2013).

RESULTS

Diameter and height increment

Diameter increment was influenced by thinning. The mean values of diameter increment of sessile oak were 6.56 ± 0.98 mm·year^{-1} in thinned plots and 4.13 ± 0.50 mm·year^{-1} in unthinned plots. The mean values of diameter increment of European hornbeam were 6.20 ± 0.62 mm·year^{-1} in thinned plots and 3.85 ± 0.37 mm·year^{-1} in unthinned plots. The diameter increment of sessile oak was 59% higher in thinned plots and 61% for European hornbeam (Fig. 1). The differences between thinned and unthinned plots were statistically significant (Table 2). Diameter increment of sessile oak in thinned and/or unthinned plots was similar to diameter increment of European hornbeam (Fig. 1). Diameter increment of sessile oak was only 6% higher than that of European hornbeam in thinned plots and 7% in unthinned plots. However, these differences were not statistically significant (Table 3).

Table 2. Effect of thinning on diameter and height increment and soil moisture

	N	*df*	*t*-value	*P*-value
Diameter increment of sessile oak (T × U)	170	134.3	4.391	< 0.000
Diameter increment of European hornbeam (T × U)	160	138.1	6.474	< 0.000
Height increment of sessile oak (T × U)	170	150.6	0.645	0.519
Height increment of European hornbeam (T × U)	160	155.3	1.276	0.207
Soil moisture (T × U)	480	449.9	7.759	< 0.000

T – thinned plots, U – unthinned plots, *N* – sample size

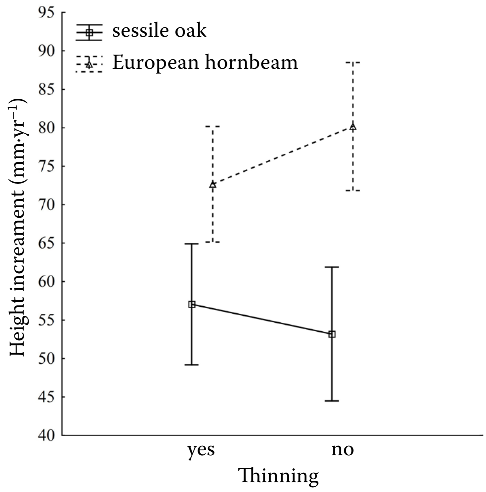

Fig. 2. Mean values of height increment (with 95% confidence interval) of sessile oak and European hornbeam for thinned and unthinned plots

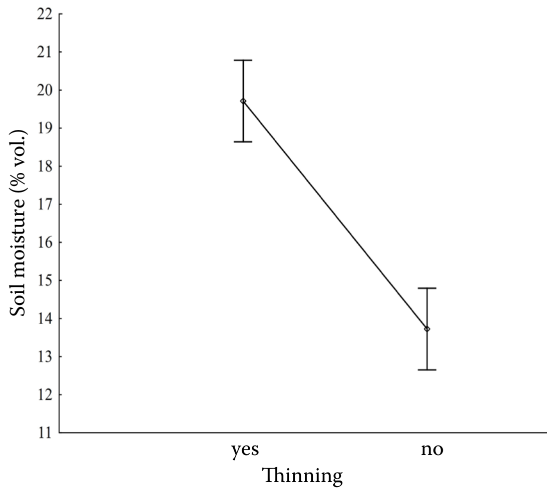

Fig. 3. Mean values of soil moisture (with 95% confidence interval) for thinned and unthinned plots

Height increment was not influenced by thinning. The mean values of sessile oak height increment were 55.92 ± 8.91 cm·year^{-1} in thinned plots and 52.31 ± 5.93 cm·year^{-1} in unthinned plots. The mean values of European hornbeam height increment were 72.66 ± 7.70 cm·year^{-1} in thinned plots and 80.17 ± 8.41 cm·year^{-1} in unthinned plots. The height increment of sessile oak was only 7% higher in thinned plots and the height increment of European hornbeam was 10% higher in unthinned plots (Fig. 2). These differences between thinned and unthinned plots were not statistically significant (Table 2). Height increment of European hornbeam was significantly higher than height increment of sessile oak in thinned plots (30%) and unthinned plots (53%) (Table 3, Fig. 2).

Soil moisture

Soil moisture was higher in thinned plots. A difference in soil moisture between thinned and unthinned plots was statistically significant (Table 2, Fig. 3). Mean values in Fig. 3 show a positive effect of thinning on soil moisture in coppice stand. Soil moisture of thinned plots was 43% higher than that of unthinned plots.

DISCUSSION

In the past, coppice stands were only clear cut (Ciancio et al. 2006) and no thinning was performed normally (Evans 1992). Now the previously practised method shifted to thinning to improve the development of trees in coppices (Montes et al. 2004). The reasons for thinning are economic, ecophysiological, and ecological.

Coppice forestry has higher production of firewood in short terms (Proe et al. 1999; Kadavý et al. 2011b). Nowadays, an increasing demand and price of renewable energy resources is noted.

Diameter increment is strongly influenced by climatic characteristics such as precipitation and air temperature (Orwig, Abrams 1997). Thinning reduces density of coppice stands and tree competition. It also increases available soil water, soil nutrients, available light and space for the remaining sprouts (Montes et

Table 3. Comparison of diameter and height increment between species

Increment	SO × EH	*N*	*df*	*t*-value	*P*-value
Diameter	thinned	181	154.2	0.616	0.538
	unthinned	149	138.1	0.909	0.364
Height	thinned	181	176.6	2.672	0.008
	unthinned	149	129.3	5.391	< 0.000

SO – sessile oak, EH – European hornbeam, *N* – sample size al. 2004). In general, if such treatment should increase the soil water level, thinning must be intense. Otherwise, a slight increase in soil moisture will be consumed very quickly without any measurable effect on the trees (Anderson et al. 1976; Aussenac, Granier 1988; Aussenac 2000). It was confirmed in the Mediterranean region that the soil moisture is higher in thinned than in unthinned plots (Cotillas et al. 2009). In our experiment, the soil moisture increased by 15% in the first year after thinning. The soil moisture in thinned plots was by 43% higher than that of unthinned plots. Recently, changes in air temperatures and distribution of precipitation have been observed. This trend will continue in the future, thus warmer and drier years can be expected (IPCC 2014). Coppicing can be a suitable management approach to altered climate conditions because the well-established root system is not as susceptible to drought as that of young seed-origin trees (Pallardy 2008). The large root system supplies a considerable amount of assimilates, nutrients and water to newly created sprouts in their initial stages of development. This explains the rapid initial growth of sprouts in comparison with seedlings (Castell et al. 1994; Crombie 1997; Miller, Kauffman 1998). Coppice could be therefore more resistant to drought than trees of seed origin (Lloret et al. 2004).

The effect of thinning on coppice diameter and height increment was studied in our experiment. Generally, silvicultural treatments affect diameter increment much more than height increment. Height growth is relatively independent of the crowding degree except for an extremely narrow spacing (Oliver, Larson 1996). The mean diameter of a tree in the coppice (holm oak) reflects the influence of both the quality of the stand and thinning intervention (Gracia, Renata 1996). Thinning has a positive effect on diameter increment. This information was confirmed for Pyrenean oak in coppice stands in Spanish central mountains after heavy (50% of the basal area removed) and moderate (35%) thinning in comparison with unthinned plots, while light thinning (25% of the basal area removed) had only a low impact on diameter increment in comparison with unthinned plots (Cañellas et al. 2004). We could confirm a positive effect of thinning on diameter increment (it was 59% higher for sessile oak and 61% higher for European hornbeam in thinned plots as compared to unthinned plots). A light thinning opens the canopy only slightly (Ducrey, Toth 1992; Cañellas et al. 2004). Heavy and moderate thinning increased the mean diameter increment by 157% for 30 years old coppice compared to unthinned plots during the first four years after thinning (Cañellas et al. 2004). The same results were obtained by Ducrey and Toth (1992) and Mayor and Rodá (1993) in holm oak coppice stands. Thinning significantly increased the mean diameter increment of holm oak sprouts by 83% over that of unthinned plots during 6–9 years after thinning (Mayor, Rodà 1993). Diameter increment of holm oak sprouts after very heavy thinning (70% and more of the basal area removed) increased 70% for 8 years old coppice and 85% for 25 years old coppice as compared to unthinned plots. According to the information mentioned above the increase in diameter increment was higher for older coppices (Ducrey, Toth 1992).

It has been documented that height growth can slow down after a very strong release especially in trees with weak epinastic control (e.g. oak) (Hamilton, Christie 1974). Results of Cañellas et al. (2004) did not show any differences between treatments in height increment of Pyrenean oak. Our results are similar – we did not find any statistically significant differences in sessile oak and European hornbeam height increments between thinned and unthinned plots. Various reactions of height growth in comparison with the diameter increment were also detected in European beech coppice (Ciancio et al. 2006). The impact of thinning on the height increment of holm oak changes with the coppice age. Thinning in young coppice (4–8 years old) had low or no positive effect on height increment, but this statement is not valid for older coppice stands (15–25 years old) (Ducrey, Toth 1992).

CONCLUSIONS

The aim of this paper was to determine the response of diameter and height increment to thinning in seven years old oak-hornbeam coppice in the southeastern part of the Czech Republic. The effect of thinning on soil moisture was also studied. The obtained results suggest that thinning increases diameter increment of the remaining sprouts of sessile oak and European hornbeam and it also increases soil moisture in the first year after thinning. However, thinning does not increase height increment. Diameter increments of both species were similar. Height increment of European hornbeam was higher than that of sessile oak.

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References

Anderson H.W., Hoover M.D., Reinhart K.G. (1976): Forests and Water: Effects of Forest Management on Floods, Sedimentation, and Water Supply. Berkeley, Pacific Southwest Forest and Range Experiment Station: 115.

Aussenac G. (2000): Interactions between forest stands and microclimate: Ecophysiological aspects and consequences for silviculture. Annals of Forest Science, 57: 287–301.

Aussenac G., Granier A. (1988): Effects of thinning on water stress and growth in Douglas-fir. Canadian Journal of Forest Research, 18: 100–105.

Brunet J., Falkengren-Grerup U., Tyler G. (1996): Herb layer vegetation of south Swedish beech and oak forests-effects of management and soil acidity during one decade. Forest Ecology and Management, 88: 259–272.

Buckley G.P. (1992): Ecology and Management of Coppice Woodlands. London, Chapman-Hall: 336.

Cañellas I., Del Río M., Roig S., Montero G. (2004): Growth response to thinning in *Quercus pyrenaica* Willd. coppice stands in Spanish central mountain. Annals of Forest Science, 61: 243–250.

Castell C., Terradas J., Tenhunen J.D. (1994): Water relations, gas exchange, and growth of resprouts and mature plant shoots of *Arbutus unedo* L. and *Quercus ilex* L. Oecologia, 98: 201–211.

Choat B., Jansen S., Brodribb T.J., Cochard H., Delzon S., Bhaskar R., Bucci S.J., Feild T.S., Gleason S.M., Hacke U.G., Jacobsen A.L., Lens F., Maherali H., Martínez-Vilalta J., Mayr S., Mencuccini M., Mitchell P.J., Nardini A., Pittermann J., Pratt R.B., Sperry J.S., Westoby M., Wright I.J., Zanne A.E. (2012): Global convergence in the vulnerability of forests to drought. Nature, 491: 752–755.

Ciancio O., Corona P., Lamonaca A., Portoghesi L., Travaglini D. (2006): Conversion of clearcut beech coppices into high forests with continuous cover: A case study in central Italy. Forest Ecology and Management, 224: 235–240.

Cotillas M., Sabaté S., Gracia C., Espelta J.M. (2009): Growth response of mixed mediterranean oak coppices to rainfall reduction. Could selective thinning have any influence on it? Forest Ecology and Management, 258: 1677–1683.

Crombie D.S. (1997): Water relations of jarrah (*Eucalyptus marginata*) regeneration from the seedling to the mature tree and of stump coppice. Forest Ecology and Management, 97: 293–303.

Ducrey M., Toth J. (1992): Effect of cleaning and thinning on height growth and girth increment in holm oak coppices (*Quercus ilex* L.). Vegetatio, 99–100: 365–376.

Evans J. (1992): Coppice forestry – an overview. In: Buckley G.P. (ed.): Ecology and Management of Coppice Woodlands. Dordrecht, Springer-Verlag: 18–27.

Forest Management Institute (2007): National Forest Inventory in the Czech Republic 2001–2004. Brandýs nad Labem, ČTK REPRO, a.s.: 224.

Gracia M., Retana J. (1996): Effect of site quality and thinning management on the structure of holm oak forests in northeast Spain. Annales des Sciences Forestières, 53: 571–584.

Hamilton G.J., Christie J.M. (1974): Influence of Spacing on Crop Characteristics and Yield. London, H.M. Stationery Office: 91.

IPCC (2014): Climate change, impacts, adaptation and vulnerability. Available at http://www.ipcc.ch/report/ar5/wg2/ (accessed Jan 12, 2016).

Kadavý J., Kneifl M., Knott R. (2011a): Biodiversity and Target Management of Endangered and Protected Species in Coppices and Coppices with Standards Included in System of Natura 2000: Methodology of Establishment of Experimental Research Plots in the Conversion to Coppice and Coppice-with-Standards and their Description. Brno, Mendel University in Brno: 58.

Kadavý J., Kneifl M., Servus M., Knott R., Hurt V., Flora M. (2011b): Nízký a střední les jako plnohodnotná alternativa hospodaření malých a středních vlastníků lesa (obecná východiska). Kostelec nad Černými lesy, Lesnická práce, s.r.o.: 296.

Kneifl M., Kadavý J., Knott R. (2011): Gross value yield potential of coppice, high forest and model conversion of high forest to coppice on best sites. Journal of Forest Science, 57: 536–546.

Konvička M., Čížek L., Beneš J. (2006): Ohrožený hmyz nížinných lesů: ochrana a management. Olomouc, Sagittaria: 80.

Lloret F., Peñuelas J., Ogaya R. (2004): Establishment of co-existing Mediterranean tree species under a varying soil moisture regime. Journal of Vegetation Science, 15: 237–244.

Mayor X., Rodà F. (1993): Growth response of holm oak (*Quercus ilex* L.) to commercial thinning in the Montseny mountains (NE Spain). Annales des Sciences Forestières, 50: 247–256.

Miller P.M., Kauffman J.B. (1998): Seedling and sprout response to slash-and-burn agriculture in a tropical deciduous forest. Biotropica, 30: 538–546.

Montes F., Cañellas I., del Río M., Calama R., Montero G. (2004): The effects of thinning on the structural diversity of coppice forests. Annals of Forest Science, 61: 771–779.

Müllerová J., Szabó P., Hédl R. (2014): The rise and fall of traditional forest management in southern Moravia: A history of the past 700 years. Forest Ecology and Management, 331: 104–115.

Oliver C.D., Larson B.C. (1996): Forest Stand Dynamics. New York, John Wiley & Sons: 544.

Orwig D.A., Abrams M.D. (1997): Variation in radial growth responses to drought among species, site, and canopy strata. Trees, 11: 474.

Pallardy S.G. (2008): Physiology of Woody Plants. San Diego, Academic Press: 464.

Pretel J. (2012): Klimatické změny a jejich dopady na život lidí. Studijní opora k akci v rámci projektu CZ.1.07/1.3.05/03.0030. Available at http://projekty.osu.cz/zemepisnove/wp-content/uploads/3.1.Klimatick%C3%A9-zm%C4%9Bny-a-jejich-dopady-na-%C5%BEivot-lid%C3%AD.pdf (accessed Jan 12, 2016).

Proe M., Craig J., Griffiths J., Wilson A., Reid E. (1999): Comparison of biomass production in coppice and single stem woodland management systems on an imperfectly drained gley soil in central Scotland. Biomass and Bioenergy, 17: 141–151.

Rackham O. (2010): Woodlands. London, HarperCollins: 592.

Rodríguez-Calcerrada J., Pérez-Ramos I.M., Ourcival J.M., Limousin J.M., Joffre R., Rambal S. (2011): Is selective thinning an adequate practice for adapting *Quercus ilex* coppices to climate change? Annals of Forest Science, 68: 575–585.

Šálek L., Stolariková R., Jeřábková L., Karlík P., Dragoun L., Jelenecká A. (2014): Timber production and ecological characteristics of trees in coppice in the Voskop nature reserve in Český kras – a case study. Journal of Forest Science, 60: 519–525.

van Calster H., Chevalier R., van Wyngene B., Archau F., Verheyen K., Hermy M. (2008): Long-term seed bank dynamics in a temperate forest under conversion from coppice-with-standards to high forest management. Applied Vegetation Science, 11: 251–260.

Viewegh J., Kusbach A., Mikeska M. (2003): Czech forest ecosystem classification. Journal of Forest Science, 49: 74–82.

Vild O., Roleček J., Hédl R., Kopecký M., Utinek D. (2013): Experimental restoration of coppice-with-standards: Response of understorey vegetation from the conservation perspective. Forest Ecology and Management, 310: 234–241.

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Corresponding author:

Ing. Barbora Fedorová, Mendel University in Brno, Faculty of Forestry and Wood Technology, Department of Forest Management and Applied Geoinformatics, Zemědělská 3, 613 00 Brno, Czech Republic; e-mail: xfedorov@mendelu.cz