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THE RESPONSE OF BASAL AREA INCREMENT IN OLD SPROUT-ORIGIN SESSILE OAK (*QUERCUS PETRAEA* (MATT.) LIEBL.) TREES DURING THEIR CONVERSION TO A COPPICE-WITH-STANDARDS

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Abstract

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This paper addresses the response of adult sprout-origin sessile oaks (*Quercus petraea* (Matt.) Liebl.) to a strong release. Our research plot was established at the Training Forest Enterprise of Mendel University in Brno (Czech Republic) at the turn of 2008/2009. The plot is situated on a plateau with mesotrofic soil in a beech-oak forest vegetation zone at an altitude of 410 m above sea level. Tree responses were monitored using precise girth measurements. During the first year after the release, the basal area increment showed a positive correlation with only the tree diameter. During the second and third year, the basal area increment was also correlated with the release intensity. During the third year, the basal area increment was explained by the tree diameter, the crown shape, and the release intensity as well as individual types of epicormic shoot occurrence. The occurrence of epicormic shoots in the lower part of the trunks and umbel-shaped crowns increased the basal area increment. In the first, second and third year after thinning, the model explained 11.79%, 11.25% and 28.99%, respectively, of the basal area increment variability. Adult trees of sprout origin responded to a strong release very early (within two years) after felling.

Keywords: sessile oak, conversion, coppice-with-standards, strong release, competition, basal area increment, generalized linear model

INTRODUCTION

Forests in the Czech Republic historically experienced a similar evolution, as described by Szymura (2012), when compared to Central European forests. Since the middle Ages, these forests were predominantly used to produce thin assortments and tan-bark in coppices and coppices-with-standards (Machar, 2008). Economic changes that took place approximately in year 1700 initiated the conversions of coppices to high forests (Szymura, 2012). A revival in the use of coppices and coppices-with-standards arrived in year 1850–1900 in response to an increased demand for tan-bark. As of year 1900, coppices on the territory of today's Czech Republic covered approximately 95,000 ha, which represents 4.1% of all timber lands, while coppices-with-standards covered approximately 60,000 ha (2.6%) (MZe, 2000). Since then, the coppice area has been decreasing. Only approximately 7,000 ha (0.23%) of coppices and 2,000 ha (0.09%) of coppices-with-standards can be found in the Czech Republic today (MZe, 2009). However, signs of revival and an increased demand for coppice and coppice-with-standards forest use may be observed at present (Utinek, 2004, 2006; Konvička *et al*., 2006). Recommendations for the re-introduction of these silvicultural systems have also been declared in the National Forest Program of the Czech Republic (ÚHÚL, 2008). This situation is not motivated by purely economic pressure, though fuel wood prices have been on the rise over the past two decades (Bufka, 2011). Biologists in particular have been promoting a change in forest management and an increase in the area of so-called open forests (e.g., Buckley, 1992; Harmer and Howe, 2003), claiming that they are necessary for stopping the decrease in biodiversity in contemporary high forests and for enhancing biodiversity in the future (Ash and Barkham, 1976; Camprodon and Brotons, 2006; Spitzer *et al*., 2008 etc.). Although the systems of coppice and coppice-with-standards management have been covered extensively in scholarly publications (e.g., Konšel, 1931; Polanský *et al*., 1956; Saniga, 2007), less is known about how to convert a quasi-high forest (which is derived from a coppice) into a coppice-with-standards (partly see, e.g., Cotta, 1845; Vyskot, 1958; Utinek, 2004). The main focus of the experiment is to find out, whether the increment of the remaining sprout-origin adult tree (potential standards) will respond at all to a strong release. We drew mainly on the hypotheses of Gea-Izquierdo *et al*. (2008) and Jones and Thomas (2004). Gea-Izquierdo *et al*. (2008) who stated the following hypotheses: a) the tree competition is virtually zero in highly open forests, and b) dominance is not permanent in these stands because the trees need to rebuild their crowns after every harvest or pruning. Jones and Thomas (2004) tested the following hypotheses to describe the responses of tree diameter growth to canopy gaps: a) upon creating a canopy gap, an immediate increase in radial growth takes place due to enhanced resource availability; however, the growth is relatively short-lived and then returns to its original value, b) a brief decrease in diameter growth resulting from shock takes place (i.e., shock from an increased supply of available light and drought) followed by an increase, culminating in a decrease to the original value that existed prior to the establishment of the gap and c) the first two processes take place concurrently; the impacts of shock responses and the immediate growth responses are balanced out, which results in a slower growth increase over several years after the canopy gap was created, followed by a return to the original values.

The main objective of this paper was to:

a) determine whether adult sprout-origin sessile oak trees, which have been tended as a high forest, will respond to strong release by an increased basal area increment and,
b) evaluate the effect of tree size, release intensity, occurrence of epicormic shoots and crown shape on the increment.

MATERIALS AND METHODS

In 2008, an experimental research plot was established in forest stand 380C10 at the Křtiny Training Forest Enterprise Masarykův les, Bílovice Forest District (Kadavý *et al*., 2011a; 2011b). The plot is situated approximately 0.5 km northeast of the Brno city border in the South Moravian region of the Czech Republic (GPS coordinates: 49°13'29.87"N, 16°40'55.391"E). The plot consists of a single-story, fully-stocked, 98-year-old stand. Around the year 1902, the previous coppice stand was clear-felled except of sporadic sessile oak standards which remained to stay. The plot was then planted with Norway spruce (*Picea abies* L.) and Scots pine (*Pinus sylvestris* L.) plants. All coniferous trees died back after a severe drought in years 1947 and 1948. Consequently, oak and hornbeam sprouts were thinned in a repetitive way. Oak trees with higher quality were supported and released. The stand was then treated as regular high forest and a rotation of 120 years was set. The predominant forest type is 2H2 (i.e., loamy beech-oak forest on plateaus and gentle slopes with *Carex pilosa*), while a minor part is of the 2X2 forest type (cornelian cherry-oak forest admixed with beech on rendzina) according to the Czech Forest Ecosystem Classification (Viewegh *et al*., 2003). The predominant biotope according to NATURA 2000 directive is L3.4 – Pannonic oak-hornbeam forests (Chytrý *et al*., 2001). The site indexes for sessile oak and wild service tree are 22 m and 18 m respectively. The plot covers 200 × 200 m (4 ha).

One hectare of the total area was clear-cut. The remaining area was strongly released (54–77% of the standing volume was removed in respect to the plot design) in order to initiate the conversion to coppice-with-standards (Kadavý *et al*., 2011a). Before thinning, the position of every living tree with a minimum DBH of 5 cm has been surveyed and recorded in the project database along with its species code, height and circumference at breast height. The sessile oak and wild service tree (*Sorbus torminalis* (L.) Crantz) individuals that met the given quality criteria (perfect health condition, at least 6 m long straight branchless trunk, a dense, long and healthy crown) were preferentially selected as potential standards and marked with a green stripe and number on the trunk. At the turn of 2008/2009, all unmarked trees and shrubs were cut down and transported out of the plot. The whole plot was subsequently fenced. A total of 420 potential standards were left on the part of the experimental plot that was designated for conversion to coppice-with-standards (3 ha), out of which 324 were specimens of sessile oak.

The following attributes were also recorded on remaining potential standards:

- stem straightness (level 1 – straight, upright stem; level 2 – slightly curved; level 3 – crooked),

- occurrence of epicormic shoots (level 1 – stem without shoots; level 2 – sporadic occurrence of epicormic shoots throughout the length of the stem; level 3 – epicormic shoots in the upper section of stem, level 4 – shoots in the lower section of stem; level 5 – abundant occurrence throughout the length of stem),
- crown shape (spike – S: crown with apparent main stem and subtle side branches, umbel – U: crown consisting of two or more main thick branches without apparent main stem, transition shape – TS: crown that could not be unambiguously ordered into any of the previous classes).

Stem straightness and crown shape were recorded only once immediately after thinning (2009, spring). The assessment of stem straightness factor took into account only the lower branchless part of the stem. Particular levels of the factor were derived on a subjective basis by ocular assessment. That is why the limits between the levels were not quantified. In order to keep the pre-set release intensity in the four repetitions, it was in some instances necessary to select standards with curvy stems that otherwise would be excluded. The occurrence of epicormic shoots was recorded at the end of each following growing season, along with circumference re-measurements. Circumferences were measured to calculate the basal area increment (BAI) of the potential standards. This was accomplished with a circumference tape (with a margin of error of 1 mm) at breast height (1.3 m) outside the growing season over three years after the thinning. To minimize errors, the spot where measurements were conducted was marked on all trees using a water-resistant marker before the initial measurements were taken. Basic characteristics of the plot before and after thinning are shown in Tab. I. Basic characteristics of potential oak standards one year prior to thinning are shown in Tab. II.

Statistical Analysis

Circumferences of all potential oak standards were converted to basal areas (before thinning and in each subsequent year after thinning). Basal area increments were calculated as differences of basal areas in subsequent years:

$$BAI_{ik} = BA_{ik} - BA_{ik-1},$$

where
BAI_{ik} ..... basal area increment of i^{th} tree in year k,
BA_{ik} ...... basal area of i^{th} tree in year k,
BA_{ik-1} .... basal area of i^{th} tree in year k – 1,
i = 1, 2, …, n .... tree,
k = 1, 2, 3 .... years after thinning.

Competition indexes (CI) was calculated for individual trees before and after felling. The competition index (CI), as defined by Rouvinen and Kuuluvainen (1997) was used. Competition indexes were calculated for all potential oak standards. The ratio between the competition index change and the value of the competition index prior to felling was used as release degree of potential standards for the release in the following way:

$$\Delta CI = \frac{(CI_{t-1} - CI_t)}{CI_{t-1} \times 100},$$

where
ΔCI .... degree of release,
CI_{t-1} ...... competition index prior to thinning,
CI_t .... competition index after thinning.

The stem straightness, occurrence of epicormic shoots and crown shape were used as dummy variables in the model, with their individual levels revealing independent estimates of parameters for the resulting model.

All independent variables were tested for multicollinearity using the variance inflation factor (VIF). A VIF value greater than 10 indicates multicollinearity (Neter *et al.*, 1990). To compare the potential standards' basal area increment during individual years, a one-way non-parametric

I: *Basic characteristics of research plot before and after thinning*

basic characteristics before thinning (year 2008)						
species	composition (%)	N/ha (pcs)	dg (cm)	hg (m)	BA (m²/ha)	V/ha (m³)
sessile oak	70.51%	311	30.3	21.1	22.48	190.3
hornbeam	9.32%	165	15.2	13.0	2.97	16.9
wild service tree	5.46%	50	21.0	16.0	1.74	12.76
larch	4.51%	15	34.9	23.2	1.44	10.87
lime	4.29%	51	18.5	15.5	1.37	11.87
other broadleaves	4.03%	63	15.9	12.5	1.27	7.67
other conifers	1.89%	6	36.4	21.8	0.6	5.12
basic characteristics after thinning (year 2009)						
species	**composition (%)**	**N/ha (pcs)**	**dg (cm)**	**hg (m)**	**BA (m²/ha)**	**V/ha (m³)**
wild service tree	12.25%	32	21.7	16.1	1.27	9.33
sessile oak	87.75%	108	32.6	21.0	9.09	79.07

II: *Basic characteristics and classification of oak potential standards one year prior to thinning*

mean DBH of standards (cm) (min–max)	95% confidence interval of mean DBH of standards (cm)	number of standards (pcs)	number of standards with epicormic shoots (pcs) (%) *					number of standards with crown shape (pcs) (%)			number of standards with stem straightness (pcs) (%)		
			level					type			level		
			1	2	3	4	5	S	U	TS	1	2	3
32.2	31.6–32.8	324	122	75	1	69	58	97	67	160	69	180	75
(21.3–48.6)			(37.7)	(22.8)	(0.3)	(21.3)	(17.9)	(29.9)	(20.7)	(49.4)	(21.3)	(55.6)	(23.1)

* classification of epicormic shoot occurrence at one year after felling

Legend:

- classification of epicormic shoot occurence: 1 – stem without shoots, 2 – sporadic occurrence of epicormic shoots throughout the length of the stem, 3 – epicormic shoots in the upper section of the stem, 4 – epicormic shoots in the lower section of the stem, 5 – abundant occurrence throughout the length of the stem
- crown shape: S – spike, U – umbel, TS – transition shape
- stem straightness: 1 – straight, upright stem, 2 – slightly curved, 3 – crooked

ANOVA (the Kruskal-Wallis test in conjunction with a multiple comparison test) was used. The traditional parametric ANOVA was not chosen because the increment values did not meet the condition of normal distribution. The test calculation was processed using STATISTICA 10 (Statsoft, 2011). To determine the influence of the above-mentioned individual variables on the basal area increment during the individual years since release, the Generalized Linear Model (GLM) was used (McCullagh and Nelder, 1989). The gamma distribution (Zuur *et al.*, 2009) was chosen as the distribution for the dependent variable. The relation $\eta = \mu - 1$ was chosen as the link function for the gamma distribution. The square root transformation was applied to increment values and provides quantities in identical orders. Generalized regression models for basal area increment in individual years after release were developed according to the following relationship:

$$BAI_{ik} = \left(\frac{1}{(\alpha_k + \beta_{jk} + X_{ijk})} \right)^2 ,$$

where

BAI_{ik}...basal area increment of subject tree,
α, β......model parameters,
X ....explanatory variables,
i = 1, 2, 3…, n....... number of trees,
j = 1, 2, 3…, m...... number of variables,
k = 1, 2, 3.............. years after thinning.

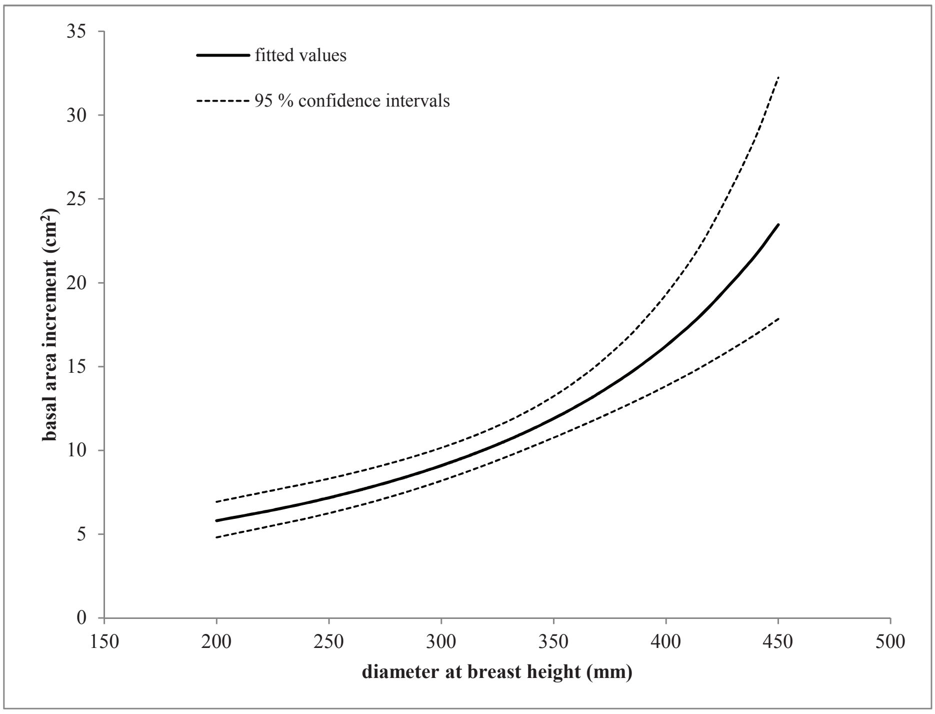
The entire process of modelling the basal area increment was performed using R 2.15.0 software (R Development Core Team, 2008). The significance level was 0.05. The testing for individual variable significance was conducted for every model. If the given variable did not contribute to model improving (i.e., its estimated parameter was insignificant according to the t-statistic value and the calculated p-value), it was left out of the model, and the model was recalculated. This procedure was repeated until a model whose remaining estimated variable parameters was statistically significant. Because the Generalized Linear Model does not specify the coefficient of determination, it is impossible to specify the part of the variance of the dependent variable that was explained by the model. This was in turn solved by calculating the residual and null deviation (Kuss, 2002). These values can be mutually compared, and their relationship is defined by Dobson (2002) as the so-called pseudo R^2. This paper employs this relationship as a goodness-of-fit-test.

RESULTS

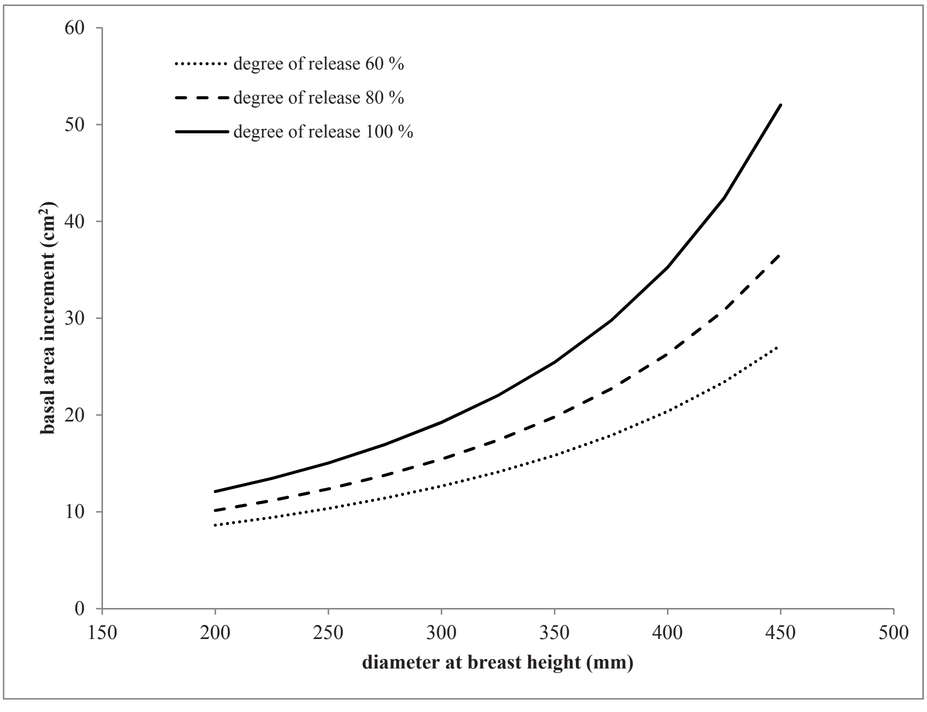
The VIF test revealed no significant multicollinearity between independent variables. The basal area increment of sessile oak potential standards during the individual years after thinning showed a statistically significant

III: *Mean basal area increment in sessile oak potential standards during the individual years after thinning with confidence intervals*

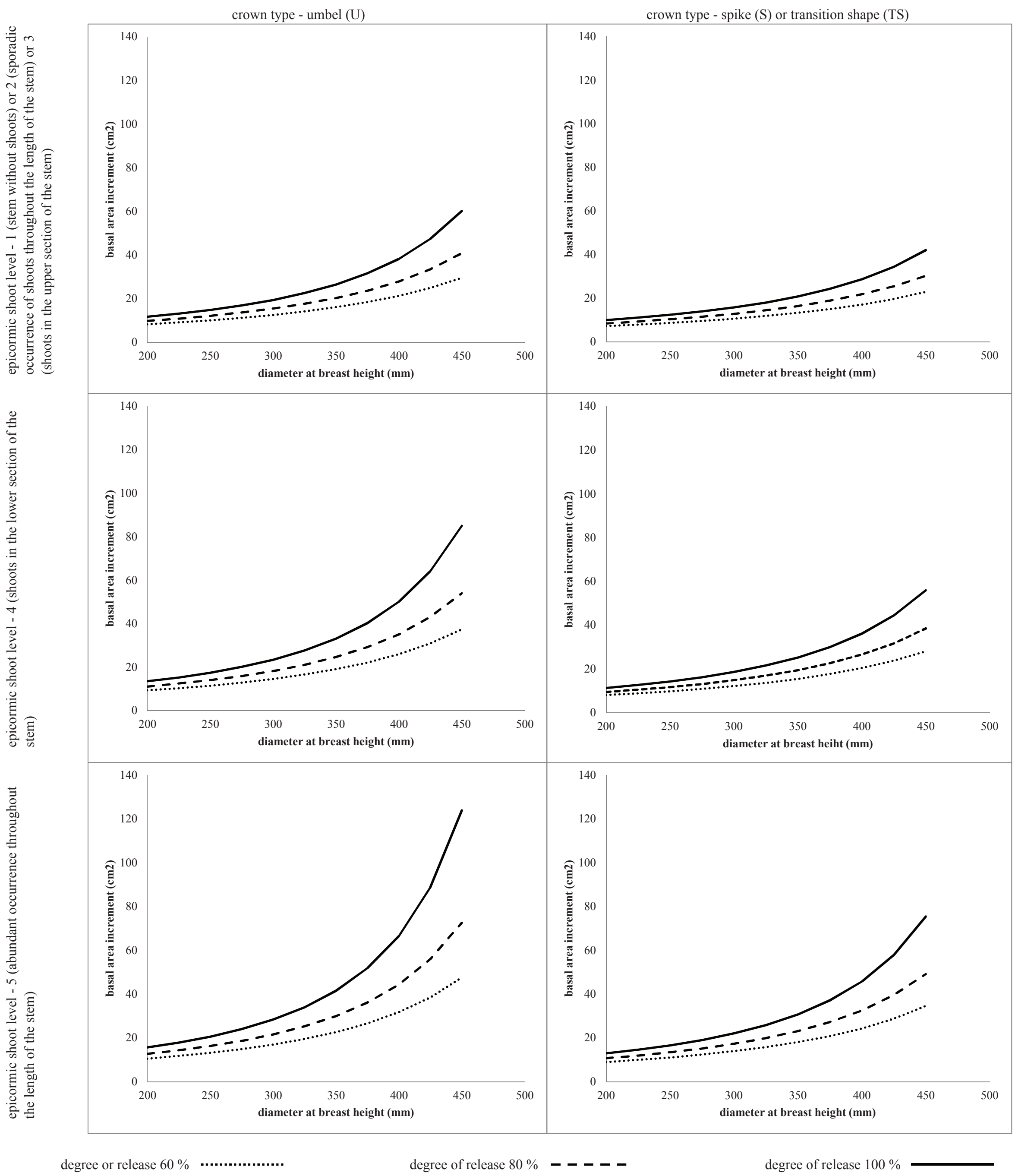
time after harvest (years)	mean BAI (cm²)	lower confidence interval (cm²)	upper confidence interval (cm²)
1	10.23	9.29	11.22
2	17.00	15.75	18.29
3	17.28	16.16	18.45



1: *Model of the basal area increment in sessile oak potential standards at the first year after thinning in relation to the diameter at breast height*



2: *Model of the basal area increment in sessile oak potential standards at the second year after thinning in relation to the diameter at breast height and different degrees of release*



3: *Model of the basal area increment in sessile oak potential standards at the third year after thinning in relation to the diameter at breast height and different degrees of release.*

difference ($p < 0.0001$). The mean basal area increment from the first year after thinning differs from the mean basal area increments in the second and third year, while the mean values from the second and third year did not display statistically significant differences. Mean basal area increment values with 95% confidence intervals are shown in Tab. III. The confidence intervals are not symmetric because the gamma distribution itself is asymmetric.

From all the variables under study, only stem straightness did not prove to be a factor that significantly affected the basal area increment in any of the models. All other variables were statistically significant in at least one model.

In the model of the basal area increment during the first year after thinning the breast height diameter came out as the only other significant factor. The value of the breast height diameter parameter indicates that the increment is directly proportional to the diameter at breast height.

IV: *Estimated parameter values of individual models for the basal area increment in sessile oak three years after thinning*

model BAI	α	β_1	β_2	β_3	β_4	β_5	pseudo R^2
year	**intercept**	**diameter at breast height**	**Δ CI**	**epicormic shoot level 4**	**epicormic shoot level 5**	**crown shape U**	
1	0.58214	–0.00083					11.79%
	(–0.0362)	(–0.0001)					
2	0.53950	–0.00060	–0.00133				11.25%
	(–0.0307)	(–0.0001)	(–0.0003)				
3	0.58580	–0.00065	–0.00138	–0.02050	–0.03910	–0.02525	28.99%
	(–0.0277)	(–0.0001)	(–0.0003)	(–0.0091)	(–0.0088)	(–0.0077)	

Legend: α, β_1, β_2, β_3, β_4 and β_5 are estimated parameters of the models; values in brackets are standard errors of estimates; pseudo R^2 gives the amount of explained variability.

It means that the higher the diameter at breast height, the higher the tree's increment. According to the calculated pseudo R^2, this model explains 11.79% of the basal area increment's variability. A graphic image of the model is presented in Fig. 1.

In the model of the basal area increment during the second year after thinning, a statistically significant influence of the diameter at breast height and the degree of release is demonstrated. The parameter values clearly demonstrate that, with increasing breast height diameter and degree of release, the basal area increment increases as well. According to the calculated pseudo R^2, this model explains 11.25% of the basal area increment variability. A graphic image of the model is presented in Fig. 2.

The model of the basal area increment during the third year after thinning encompasses the highest number of demonstrably significant factors. Apart from the diameter at breast height and degree of release, the increment is also affected by the number of epicormic shoots and by crown shape. The basal area increment in the third year after thinning increases with increasing breast height diameter and degree of release, and it is higher even in cases when the epicormic shoot of level 4 or 5 appears on the tree as well as in cases in which the crown has an umbel-type shape. According to the calculated pseudo R^2, this model explains 28.99% of the basal area increment's variability. A graphic image of the model is presented in Fig. 3.

Estimated parameter values of all three models and their pseudo R^2 values are shown in Tab. IV. It is obvious that the basal area increment increases with increasing DBH and release intensity. Along with this finding, the basal area increment is positively affected by strong occurrence of epicormic shoots (factor level 4 and 5) and crown type (factor level U-umbel). In the third season after release, the share of explained variance was higher after other explanatory variables were taken into account.

DISCUSSION

Our results have demonstrated that trees which are more released after thinning have a different increment from those that were less released, i.e., that a different diameter structure in the stands develops according to the applied thinning intensity. This finding agrees with results by Montes *et al.* (2004), who found that both moderate and heavy thinning had a similar influence on the structure of an oak coppice but that the resulting effect after light thinning is completely different.

Also, we did not detect any occurrence of negative basal area increment during three subsequent years of observation. This was probably achieved by utilization of a precise measurement method (circumference re-measurements using girth tape) and also by the fact that the best tree had been strongly released at the beginning of the experiment.

The category of larger trees and their response to growth change has been used for estimates of stand growth and production in competition models for a long time (Wykoff, 1990; Monserud and Sterba, 1996; Yang *et al.*, 2009; Ledermann, 2010; Pretzsch and Biber, 2010). A hypothesis about the inability of large (old) trees to increase their growth as a result of stand density reduction as tested in this paper has been used also by Latham and Tappeiner (2002) and York *et al.* (2010). These papers focused primarily on conifers. However, from the perspective of hypothesis definition, they are very similar methods and are therefore applicable. A decrease in increment is generally expected when a tree reaches a certain age limit (Weiner and Thomas, 2001). The increment may be enhanced by suitable stand care, such as tree release. Our results reveal that adult sessile oaks of sprout origin are already capable of a fast response to release through increased increment during the second year after release. The fast response may be explained using a theory by Jones and Thomas (2004), in which tree release is followed by a brief drop in growth due to shock (a shock caused by the increased supply of available light and drought), followed by an increase; upon culmination, the growth returns to the original value that it had prior to the creation of the gap. A similar response speed to release is given by Johnson *et al.* (2009) for young white oak stands (*Quercus alba* L.) and by York *et al.* (2010) for old giant sequoia trees (*Sequoiadendron giganteum*

(Lindl.) J. Buchholz). Latham and Tappeiner (2002) showed a Douglas fir (*Pseudotsuga menziesii* Engelm.) response to release through increased increments from 5 to 25 years after thinning. York *et al.* (2010) studied the radial increment of old giant sequoia trees as a response to release and found that released trees, regardless of the degree of their release, reached higher increments than unreleased trees, reaching the highest increments at three years after release. According to our results, the trees had already responded during the second and third year after release, with increment increases that were not statistically significantly different during the two last years of monitoring. This trend might have been caused by the occurrence of a seed year during the third year after release. In 2011, the Czech Republic experienced a strong mast year for oaks. It is generally known that the deposition of assimilates in the trunk during such years is not ideal for trees. Stem growth during such years is considered to be secondary, as papers dealing with carbon allocation in individual sections of tree have shown (Cannell, 1989; Cannell and Dewar, 1994; Lacointe, 2000; Génard *et al.*, 2008; Genet *et al.*, 2010). This phenomenon is manifested by narrow growth rings in mast years as a result of a negative correlation between seed production and growth ring width (Koenig and Knops, 1998). In this respect, it must also be mentioned that different amounts of assimilates are deposited at individual height levels of the tree trunk (Farrar, 1961; Larson, 1963; Fayle, 1973; Šmelko, 1975; 1982). The process of assimilates deposition can be influenced primarily by tending measures, applying fertilizer (Myers, 1963; Mitchell and Kellogg, 1972; Snowdon *et al.*, 1981; Thomson and Barclay, 1984; Valinger, 1992; Tasissa and Burkhart, 1997; Peltola *et al.*, 2002) or stand irrigation (Wiklund *et al.*, 1995).

The increased increment response to release was monitored in old Douglas fir trees (Newton and Cole, 1987), lodgepole pine (*Pinus contorta* Douglas ex Loudon) (Waring and Pitman, 1985), eastern white pine (*Pinus strobus* L.) (Cole *et al.*, 2004), ponderosa pine (*Pinus ponderosa* Douglas ex C. Lawson) (McDowell *et al.*, 2003) and Scots pine (Martínez-Vilalta *et al.*, 2007; DeSoto *et al.*, 2010). Latham and Tappeiner (2002) determined that there was an increase of 10–38% in the basal area increment in response to thinning in an old stand of Douglas fir, ponderosa pine and sugar pine (*Pinus lambertiana* Douglas), with approximately 30% of the trees experiencing an increase in their increments of more than 50% that lasted for more than 20 years. Despite the general assumption that smaller trees tend to respond to a release by an increased basal area increment (DiGregorio *et al.*, 1999; Jones and Thomas, 2004), more trees of bigger diameters responded to the release by increasing their basal area increment in the Sakhalin fir (*Abies sachalinensis* (F. Schmidt) Mast.) (Miya *et al.*, 2009). The highest increase in basal area increments was observed in mizunara oak (*Quercus crispula* Blume) during the second to sixth years after release, the Sakhalin fir in the first to sixth year, birch (*Betula ermanii* Cham.) in the second to fifth year and maple (*Acer mono* Maxim.) in the second to sixth year after release (Miya *et al.*, 2009).

Old trees may respond to release by forming epicormic shoots at lower sections of their trunks (O'Hara *et al.*, 2008), as described by Cañellas *et al.* (2004) for the Portuguese oak (*Quercus faginea* Lam.). Our work reveals that the basal area increment is positively correlated with the number of epicormic shoots in adult sessile oak trees of sprout origin. This statement contradicts the current results that connect the epicormic shoot occurrence with radial (cambial) growth (Spiecker, 1991; Colin *et al.*, 2008). This finding may be explained by the strong release of trees which until recently have been cultivated under normal (dense) canopy closure of a high forest. However, it may be expected that apart from the positive effect, i.e., radial growth increases, a negative effect will occur in the same trees in the form of crown drying (Hochbichler, 1993). This effect may be prevented by pruning, which could be conducted a) through a natural pruning of the trunks by the growing lower story or b) mechanically (Kerr and Harmer, 2001). Pruning positively enhances the quality of the final characteristics of strongly released trees (Spiecker, 1991). Kodani *et al.* (2010) discovered that the number of epicormic shoots in the Mongolian oak (*Quercus mongolica* Fisch. ex Turcz.) was inversely proportional to the stem volume after thinning. From this conclusion, we may deduce that trees with smaller stem volumes have smaller diameters at breast height, which means that thinner trees produce more epicormic shoots after thinning. Colin *et al.* (2008) found that sessile oak trees that were cultivated from the beginning of their development in closer spacing (density) produced the longest epicormic shoots. Considering these findings, it may be concluded that it is desirable to release thinner trees and cultivate them when they are as released as possible to achieve the highest basal area increment possible. This finding fully corresponds with results obtained over the course of our research. However, we must bear in mind that increased increments represent only a temporary effect that occurs after thinning. One of the factors limiting this effect is that the trees with the highest number of epicormic shoots will be eliminated naturally (i.e., die) due to competition from the stand (Colin *et al.*, 2008).

SUMMARY

The paper describes basal area increment response of old sprout-origin oaks to strong release that initiated a long-term conversion to coppice-with-standards.

The research plot was situated within a quasi-high forest stand (sprout origin stand tended as high forest) in area managed by the Masarykův les Křtiny Training Forest Enterprise (a special-purpose facility of Mendel University in Brno). The objective of this paper was to establish whether the process of converting such stands can stimulate radial growth.

Sprout-origin adult sessile oak trees of approximately 100 years of age are capable of responding to strong release by a significant increase in basal area increment within a very short time. The basal area increment increased over three subsequent years after release, but the difference between second and third year was not significant. This could indicate quite early decline of the response.

In the first year after release, the basal area increment was correlated only with the DBH, while the release intensity had no effect on the increment. In the second year after release, also release intensity became a significant regressor of the basal area increment. In the third year, also the influence of epicormic shoots occurrence and crown shape became significant. Trees with epicormic shoots in the lower section of stem and trees with abundant occurrence of shoots throughout the length of stem showed significantly higher basal area increment. Also, trees with umbel-shaped crown showed significantly higher increment than those with spike-shaped crowns.

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