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PRODUCTION POTENTIAL AND QUALITY OF SESSILE OAK (*QUERCUS PETRAEA* LIEBL.) IN DIFFERENT TYPES OF MIXTURES

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Abstract

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Three variants of growing sessile oak (maturing high forest) on typical fertile sites of lower elevations in the Czech Republic were compared from the production and quality point of view. The variants were as follows: mixed forest unmanaged more than 30 years, mixed forest and pure stand subjected to standard management measures based on positive selection. Surprisingly, no essential differences were found either in the production potential or in the quality of sessile oak at comparing the managed mixed forest and the monoculture. A higher number of crop oak trees in the monoculture was compensated in the mixed forest by the representation of other tree species. The unmanaged mixed forest exhibited worse quality of oak crowns, which closely correlates with the volume yield. Therefore, it is recommended to apply tending measures on the principle of thinning from above with the comprehensive management of crowns in selected targeted trees even at their higher age.

sessile oak, mixed forest, monoculture, production, quality, tending

Sessile oak (*Quercus petraea* LIEBL.) and pedunculate oak (*Quercus robur* L.) are timber species of commercial significance in the Czech Republic and their wood is considered best and most valuable. The most valuable veneering wood is obtained from healthy old oak trees with fine annual rings (Vyskot, 1958). Important silvicultural characteristics of oak include the liability to branch spreading upon the growing space release, development of eccentric crowns and non-development of continual axis. Moreover, oak trees show a distinct tendency to phototropism; this is why stem curvature may occur. In general, the tending of oak is relatively complicated (Saniga, 2007).

According to Klíma (2004), sessile oak is one of important commercial tree species both as the main timber species and as a species constituting high-quality mixtures with other commercial tree species, namely with beech, pine and larch. To maintain quality and sound formation of wood, oak needs a protective secondary stand of accompanying tree species as early as in the small pole stage (Svoboda, 1955). Štefančík and Strmeň (2011) mention a beneficial effect of hornbeam for the development of co-dominant, namely target, trees. However, the growing of mixed stands has its specific features such as different light requirements of the tree species and their different natural growth rhythm (Assmann, 1968).

The comparison of the production of mixed oak stands and oak monocultures did not bring unambiguous conclusions. Species with high root energy such as oak, fir or alder can win access to soil layers that are generally difficult to penetrate for roots of other tree species, which may lead to a better supply of nutrients for the whole stand. In general, we can assume that any deepening and extension of soil space engaged by roots would increase the production capacity. Mixed stands with oak in the upper layer and a natural or artificial lower layer of beech, hornbeam, linden and possibly also fir can produce much more mass and dry matter than a pure oak stand. Due to the competition of the lower and upper storey, however, it is necessary to count with impaired increment in the upper oak layer. (Assmann, 1968). Poleno (1979; in: Kantor,

Knott, 2000) showe that the generally established assumption about the higher production of mixed stands does not have to be fulfilled especially if the mixture consists of species with considerably different production potentials. Kantor *et al.* (2001) claim that indisputable advantage of stands mixed of multiple species is their expected high ecological stability. Even massive decay of one or several tree species does not have to result in stand disintegration. According to Klíma (2004), oak competes very well in these diverse mixtures and can form high-quality stems. Similarly, Slodičák (2007) maintains that oak stands with a more complex stand structure, i.e. with a richer tree species composition and greater vertical stand articulation exhibit optimal development.

According to Košulič (2010), the growth of the upper and lower storey depends on the degree of upper oak layer release. Heavier opening would increase the growth of both storeys. Total production of a two-storeyed oak stand with the lower layer of beech surmounts the production of a homogeneous oak stand in dependence on the total production age. At a rotation of 150 and 200 years, the increase amounts to approx. 10% and 20%, respectively.

According to Schädelin, typical thinning from above with positive selection is the quality thinning, which aims at a supreme stand quality (Saniga, 2007). Following the tending models applied in the Czech Republic (Slodičák, Novák, 2007) in stands with the upper stand height of 20–24 m, we continue in the positive selection while the number of crop trees can be reduced to 200–300 per hectare. Košulič (2010) recommends structural thinning that ought to be focused on the target state with about 50–60 C1-trees per hectare since early tending measures. This indicates that at the end of the growth stage of thicket and the beginning of the pole growth stage, the number of C1-trees to be selected in the oak stand should be 100–120/ha.

The goal of this study is to compare three variants of oak stand management (mixed forest unmanaged, mixed forest and pure stand subjected to standard management) from the production and quality point of view.

METHODOLOGY

Three following variants of growing oak stands were chosen for the purposes of our experiment: unmanaged mixed forest "Mix–" (PRP "Jurčova chata"), mixed forest under standard main layer management "Mix+" (1x per decennium), and pure stand "Mono". The experimental stands (Tab. I) are situated on fertile sites of lower elevations operated by the Training Forest Enterprise Masaryk Forest Křtiny (Mendel University in Brno) and they were chosen so that the age and site conditions (FSC: beech with oak on the rich site) of the respective variants are as much similar as possible. Mean annual temperature ranges about 7.5 °C and mean annual precipitation amount is 600 mm.

Two representative research plots (RP) sized 30 × 30 m were established in each variant (six RPs in total). On these plots, all trees (DBH > 7 cm) were measured for diameter at breast height and tree height.

Only the sessile oak individuals were measured for other characteristics – coenotic position of oak, crown setting height, crown quality class and stem quality class according to the combined Assmann-Polansky classification (Tab. II). Individual parameters of oak were compared among the variants by using the Kruskal-Wallis test at a level of statistical significance $\alpha = 0.05$.

RESULTS

Production

The dominant species in all experimental variants is sessile oak; admixed species are hornbeam and small-leaved linden. The experimental localities Mix– and Mix+ include also European beech in the admixture. The locality Mix+ is the only one that contains admixed European larch (Tab. III).

The highest mean diameter of oak was detected in the variants Mix+ and Mono; the significantly lowest value was found in the variant Mix– (Tab. IV, Fig. 1 a, b). The most frequently measured mean diameter of oak in the Mix– variant was ca. 22 cm. In the variants Mix+ and Mono, the mean diameter of oak trees was identically ca. 26 cm (Fig. 1 c).

The assessment of the oak height structure (Tab. V) revealed that in all experimental variants

I: *Site conditions of individual research plots by variants*

	Unmanaged mixed stand (Mix–)		Managed mixed stand (Mix+)		Monoculture (Mono)	
	RP 1	**RP 2**	**RP 3**	**RP 4**	**RP 5**	**RP 6**
Stand	36A7	36A7	36A7	40C7	51A7	51A7
FSC*	3B	3B	3B	3B	2S	2S
Stand density	10	10	10	10	10	10
Age	71	71	71	74	73	73
GPS –N,E	49°16'53.813" 16°39'8.868"	49°16'55.332" 16°39'11.295"	49°16'58.201" 16°39'10.005"	49°17'7.498" 16°39'8.658"	49°15'22.866" 16°38'59.399"	49°15'21.679" 16°39'2.031"

*Forest Site Complex

II: *Classifications chosen for sessile oak*

Coenotic position of sessile oak - Height classes according to Assmann	
Height class	**Tree characteristic**
1	Dominant tree
2	Co-dominant tree
3	Secondary dominant tree
4	Intermediate tree
5	Subdominant tree
Classification of crown quality in sessile oak according to Assmann	
Crown quality	**Tree crown characteristics**
1	oversized, all-round evenly developed with dense foliage
2	normal size, almost evenly developed with sufficiently dense foliage
3	middle-sized, unevenly developed or with insufficiently dense foliage
4	Small, with serious malformations and thin foliage
5	Very small, poorly developed with very thin foliage
Classification of stem form and quality in sessile oak according to Polansky	
Stem quality	**Stem form and quality characteristics**
1	Upright cylindrical stem without knots
2	Rather upright but knotty stem
3	Curved, considerably knotty stem
4	Very poorly formed stem (forked, crooked)

III: *Representation of tree species in the respective experimental variants*

Variant	**Mix–**			**Mix+**			**Mono**		
Species	**trees/ha**	**G ($m^2.ha^{-1}$)**	**%**	**trees/ha**	**G ($m^2.ha^{-1}$)**	**%**	**trees/ha**	**G ($m^2.ha^{-1}$)**	**%**
Oak	878	31.19	82	428	20.51	54	672	31.75	88
Hornbeam	100	0.78	2	183	3.24	9	133	1.66	5
Linden	211	3.64	10	300	6.94	18	11	2.26	6
Beech	83	2.52	6	94	3.69	10	6	0.25	1
Larch	-	0.00	0	28	3.28	9	-	0.00	0
Sum	1272	38.13	100%	1033	37.65	100%	822	35.93	100%

the greatest share of oak individuals occurred in the main level. Oak achieved the greatest values of mean tree height in the Mono and Mix+ variants while the tree height in the Mix– variant was significantly lower (Tab. VI, Fig. 2) The trend of height growth of oak in relation to diameter at breast height was similar in all experimental variants (Fig. 3). The greatest average crown setting height in oak trees was found in the localities Mix– (10.5 m) and Mix+ (10.2 m) while the crown setting height in the variant Mono was significantly lower (8.4 m).

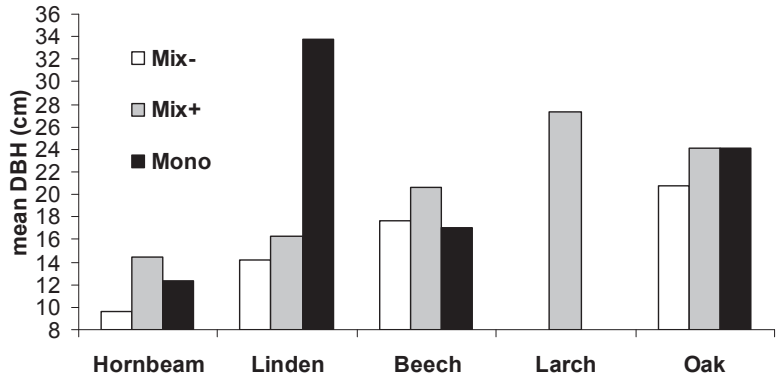
Oak reaches the highest mean-tree volume in the variants Mix+ (0.533 m^3) and Mono (0.526 m^3) with the differences being insignificant and the significantly lowest values were found in the variant Mix– (0.380 m^3) (Tab. VII). In all cases, the volume yield of sessile oak depended on the degree of crown development (Fig. 4).

Due to the highest number of trees, the highest total standing volume was detected in the variant Mix–; standing volumes of variants Mono and Mix+ were by ca. 5% lower and identical (Tab. VII). The highest hectare standing volume only in oak was detected in the variant Mono in spite of the fact that the number of trees was lower than in the variant Mix–. The lowest hectare standing volume was found in the variant Mix+ with the lowest number of oak trees (Tab. VII).

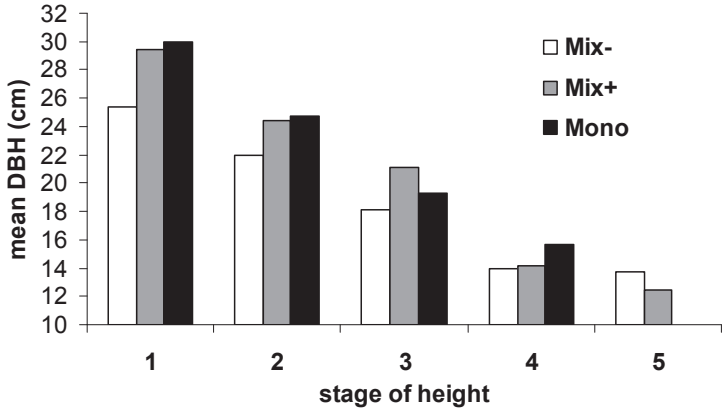
The least (significantly only with Mix+) favourable slenderness ratio of oak crop trees was found in the variant Mix– (0.95) while the most favourable values of slenderness ratio were measured in the variants Mix+ (0.85) and Mono (0.89), their statistical difference being insignificant.

Oak stem and crown quality and crop trees:

In relative terms, the comparison of all variants showed that the highest number of oak trees with above-average stem form and quality (Class 1) was surprisingly detected in the variant Mix– (Tab. VIII), which also exhibited the highest relative number of poor-quality stems (Class 4). The relative numbers of oak trees in other stem quality classes were rather equable in the respective variants.



1a)



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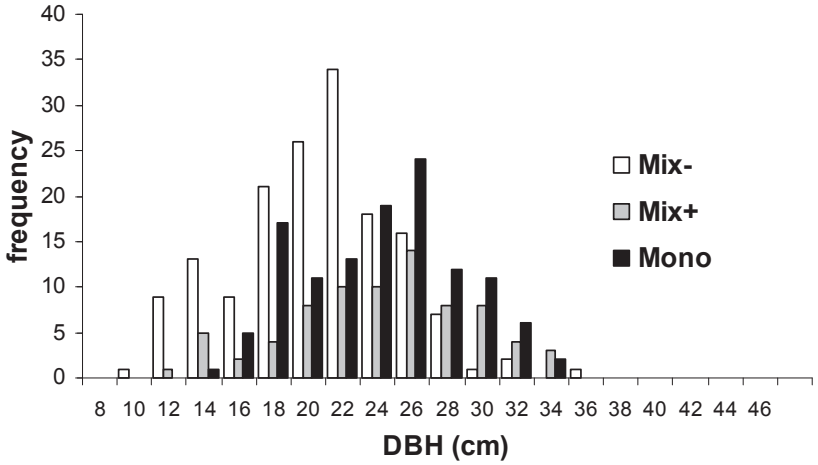


1c)

1: *(a) Mean diameter of tree species by variants; (b) mean diameter of sessile oak according to coenotic position in the respective variants; (c) abundance of sessile oak according to diameter at breast height*

The highest number of oak trees with the above-average crown quality (Class 1) was found in the variant Mix+. In assessing the representation of other crown classes, the variant Mix+ was comparable with the variant Mono. By contrast, the Mix– variant showed the highest number of oak trees with crowns of poor quality.

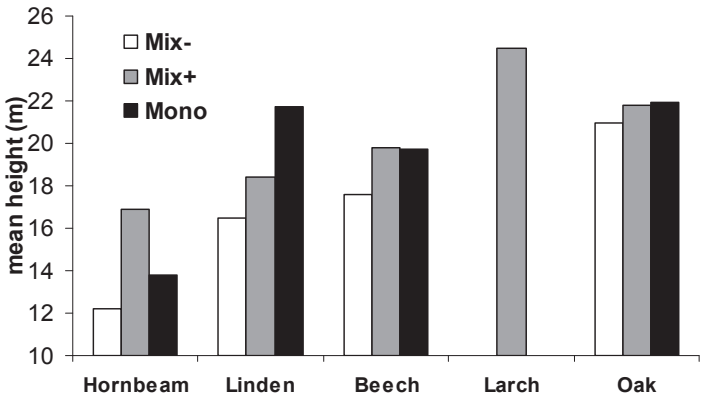
Crop oak trees we define as trees with the above-average stem and crown quality (Class 1 or Class 2). The Mono variant exhibited 189 crop oaks per hectare, i.e. 23% of the total number. The Mix–

IV: *DBH of tree species by variants*

Species	Variant	Average	Median	Standard deviation	Minimum	Maximum
Hornbeam	Mix–	9.64	8.68	2.57	7.00	16.25
	Mix+	14.41	13.95	4.14	7.55	24.80
	Mono	12.36	11.95	2.34	9.10	20.15
Linden	Mix–	14.24	14.50	4.10	7.10	22.50
	Mix+	16.29	14.58	5.40	8.75	33.25
	Mono	33.80	33.80	12.45	21.35	46.25
Beech	Mix–	17.68	16.65	8.47	8.00	32.35
	Mix+	20.64	21.05	8.40	9.35	37.85
	Mono	17.00	17.00	0.00	17.00	17.00
Larch	Mix–	-	-	-	-	-
	Mix+	27.37	28.00	1.52	24.75	28.85
	Mono	-	-	-	-	-
Oak	Mix–	20.78	21.08	4.56	10.15	35.75
	Mix+	24.16	24.85	5.18	12.45	34.05
	Mono	24.11	24.40	4.51	14.45	34.85

V: *Number of sessile oak trees per hectare by height classes*

Height class	Variant					
	Mix–		Mix+		Mono	
	trees/ha	%	trees/ha	%	trees/ha	%
1	161	18%	83	19%	89	13%
2	439	50%	255	60%	422	63%
3	156	18%	56	13%	155	23%
4	61	7%	28	7%	6	1%
5	61	7%	6	1%	0	0%
Total	878	100%	428	100%	672	100%

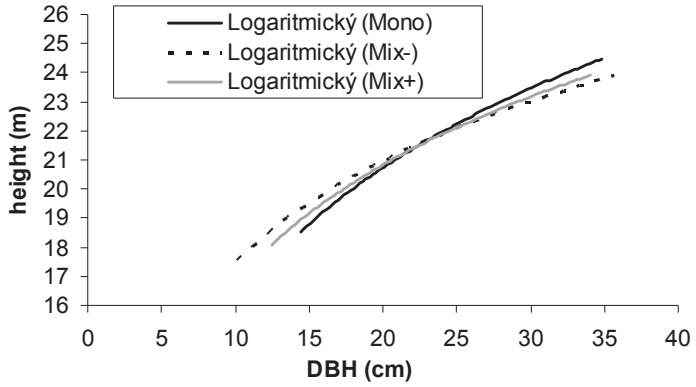


2: *Average height of tree species by variants*

variant contained after conversion 250 crop trees per hectare, i.e. 20% of the total number. The Mix+ variant contained the lowest number of crop oak trees (156), i.e. 15% of the total number.

DISCUSSION AND CONCLUSIONS

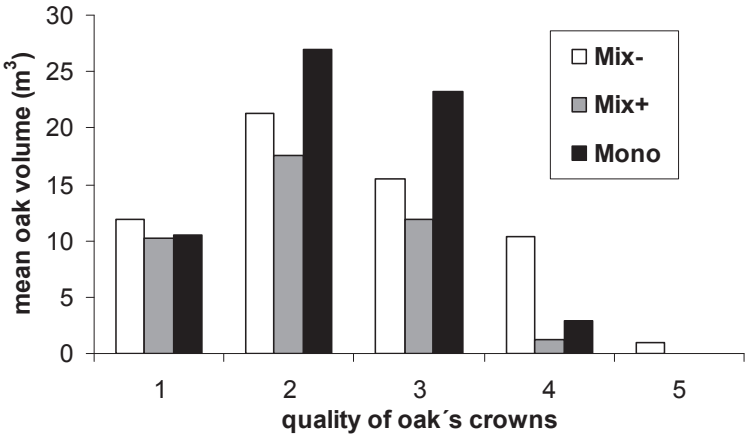
Three variants of growing sessile oak (maturing high forest) on typical fertile sites of lower elevations in the Czech Republic were compared from the production and quality point of view. The variants were as follows: mixed forest unmanaged more than 30 years, mixed forest and pure stand subjected to



3: *Height curves of sessile oak by variants*

VI: *Height of tree species by variants*

Species	Variant	Average	Median	Standard deviation	Minimum	Maximum
Hornbeam	Mix–	12.2	11.5	3.48	6.3	20.6
	Mix+	16.9	16.7	3.08	11.3	21.7
	Mono	13.8	13.8	2.36	10.0	21.0
Linden	Mix–	16.5	17.2	3.90	9.4	22.2
	Mix+	18.4	18.4	3.17	11.3	23.2
	Mono	21.7	21.7	1.50	20.2	23.2
Beech	Mix–	17.6	17.8	5.25	11.1	26.2
	Mix+	19.8	21.4	3.31	11.2	23.5
	Mono	19.7	19.7	0.00	19.7	19.7
Larch	Mix–	-	-	-	-	-
	Mix+	24.5	24.6	0.58	23.8	25.4
	Mono	-	-	-	-	-
Oak-Total	Mix–	21.0	21.1	1.84	14.1	25.4
	Mix+	21.8	22.1	1.56	14.6	23.5
	Mono	21.9	22.1	1.40	17.1	24.4



4: *Mean-tree volume of sessile oak according to crown quality in the respective variants*

standard management measures based on positive selection.

Principles for the tending of mixed stands with oak based on positive selection in the main layer are generally valid and verified by long-term research and practice (e.g. Klíma, 2004; Saniga, 2007; Slodičák, 2007). The need of the diameter and height differentiation of oak stands and the beneficial effect

VII: *Volume of tree species and total stand volume by variants*

Species	Variant	Mean-tree volume in bark (m^3)	Number of trees per ha	Volume in bark per ha (m^3)
Hornbeam	Mix–	0.041	100	4.11
	Mix+	0.147	183	26.94
	Mono	0.076	133	10.17
Linden	Mix–	0.153	211	32.28
	Mix+	0.230	300	68.89
	Mono	1.185	11	13.17
Beech	Mix–	0.322	83	26.83
	Mix+	0.422	94	39.89
	Mono	0.220	6	1.22
Larch	Mix–	-	-	-
	Mix+	0.516	28	14.33
	Mono	-	-	-
Oak	Mix–	0.380	878	333.33
	Mix+	0.533	428	228.06
	Mono	0.526	672	353.44
Total	Mix–	0.312	1272	396.56
	Mix+	0.366	1033	378.11
	Mono	0.460	822	378.00

VIII: *Number of trees per hectare by variants and according to sessile oak stem quality*

Oak stem quality	Variant					
	Mix–		Mix+		Mono	
	trees/ha	%	trees/ha	%	trees/ha	%
1	61	7%	11	2%	11	2%
2	317	36%	183	43%	272	40%
3	444	51%	217	51%	383	57%
4	56	6%	17	4%	6	1%
Total	878	100%	428	100%	672	100%

IX: *Number of trees per hectare by variants and according to sessile oak crown quality*

Oak crown quality	Variant					
	Mix–		Mix+		Mono	
	trees/ha	%	trees/ha	%	trees/ha	%
1	100	11%	67	16%	67	10%
2	283	32%	172	40%	283	42%
3	267	31%	167	39%	272	41%
4	200	23%	22	5%	50	7%
5	28	3%	0	0%	0	0%
Total	878	100%	428	100%	672	100%

of sub-dominant secondary tree species on the development of crop oaks are sufficiently known (e.g. Klíma, 2004; Štefančík and Strmeň, 2011). However, only a few works have been devoted to the complex production and qualitative analysis of various oak growing strategies. The experiment established by us provokes a number of questions that have to be cleared in the future; several essential ones are listed below:

1. What is the production and quality of oak in the unmanaged (more than thirty years) mixed stand as compared with managed variants?

The unmanaged plot is characterized by the significantly lowest volume production of oak; however, the total standing volume is by about 5% higher thanks to the highest number of oak trees. The stability of oak (valuated by slenderness ratio) was the least favourable of all variants, yet sufficient.

If we classify the good quality of stem and crown by Class 1 and Class 2, we find out that the share of high-quality stems is comparable but the quality of crowns is markedly worse. These conclusions are corroborated also by Klíma (2004).

2. Is the production and quality of oak in the managed mixed stand higher than in the oak monoculture?

Assmann (1968) claims a general advantage of mixed stand to be the deepening and extension of rooted soil space, which increases the production capacity. Mixed stands with oak in the upper layer and with the natural or artificially grown lower layer of beech, hornbeam, linden and/or fir produce more mass and dry matter than a pure oak stand. On the other hand, however, the competition of the lower and middle layer may reduce increment in the upper oak layer.

In our experiment, the monoculture actually exhibited a significantly lower proportion of oak and other species in the lower layer as compared with the mixed stand. Our results indicate that the volume yield of oak does not differ significantly if the two variants are compared. Moreover, the quality of stem and crown was the same, too. According to mensurational tables (Černý *et al*., 1996), the hectare standing volume of oak monoculture should be 320 m^3 for the given yield class 4 (24). Total hectare standing volumes of mixed stand and monoculture were identical (378 m^3). The total number of trees (1033) and basal area (64.8 m^2) were a little higher in the variant Mix+ than in the monoculture (822; 62.4 m^2). This shows that the two variants did not differ in terms of production and quality.

3. Will the managed mixed stand be capable to assure a sufficient number of crop oaks (trees with the crown quality class 1 or 2 and the stem quality class 1 or 2) as compared with the monoculture?

The number of oak trees and hence their total volume must be logically higher in the monoculture (in our case by 35%) than in the mixed stand (Mono 672 oak trees, 353 m^3 vs. Mix+ 428 oak trees, 228 m^3). The number of crop oak trees per hectare in the variants Mono was 189 (23% of the total number of oaks) and Mix+ only 156 (15% of the total number of oaks), respectively. Nevertheless, in the mixed stand it is possible to add crop trees and volume of the dominant trees of other species. In our case, we can count with beech, hornbeam, linden and larch of mean diameter at breast height ca. 25 cm and height ca. 20 m. Consequently, the number of potential crop trees will increase to 193 (156 oaks, 17 lindens, 10 beeches, 5 hornbeams and 5 larches) per hectare. According to the recommended tending models (Slodičák, Novák, 2007), the number of crop trees in these stands whose height is 20–24 m should be 200–300. Košulič (2010) recommends a target number ranging between 50–60 crop trees per hectare. Similarly, the French model counts with the selection of 70–100 crop trees per hectare (Oswald, 1981) at the rotation period of 150–210 years (Bonneau, 1995). This indicates that the number of crop trees in our experiment is sufficient.

In our experiment, no production or quality advantage of mixed stands with oak was demonstrated as compared with the oak monoculture. However, the growing of mixed stands can be generally recommended for preliminary prudence reasons (wider supply of assortments of various timber species), theoretically more favourable microclimatic and soil conditions and higher biodiversity. Crown quality in oak closely relates to volume yield. The period without management showed in the impaired quality of crowns. This is why we recommend to apply tending measures based on thinning from above along with the comprehensive management of crowns in the selected crop trees even at higher age in spite of the fact that first tending measures are most important for high-quality development of oak.

SUMMARY

Three variants of growing sessile oak (maturing high forest) on typical fertile sites of lower elevations in the Czech Republic were compared from the production and quality point of view. The variants were as follows: mixed forest unmanaged more than 30 years, mixed forest and pure stand subjected to standard management measures based on positive selection. The unmanaged plot is characterized by the significantly lowest volume production of oak; however, the total standing volume is by about 5% higher thanks to the highest number of oak trees. The stability of oak (valuated by slenderness ratio) was the least favourable of all variants, yet sufficient. If we classify the good quality of stem and crown by Class 1 and Class 2, we find out that the share of high-quality stems is comparable but the quality of crowns is markedly worse. The monoculture actually exhibited a significantly lower proportion of oak and other species in the lower layer as compared with the mixed stand. Our results indicate that the volume yield of oak does not differ significantly if the two variants are compared. Moreover, the quality of stem and crown was the same, too. The number of crop oak trees per hectare in the variants Mono was 189 (23% of the total number of oaks) and Mix+ only 156 (15% of the total number of oaks), respectively. Nevertheless, in the mixed stand it is possible to add crop trees and volume of the dominant trees of other species. In our case, we can count with beech, hornbeam, linden and larch of mean diameter at breast height ca. 25 cm and height ca. 20 m. Consequently, the

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REFERENCES

ASSMANN, E., 1968: Náuka o výnose lesa. (*Forest Yield Theory*) Bratislava, PRÍRODA, 474 s.

BONNEAU, M., 1995: Sessile oak seedling fertilization and leaf mineral composition in western France. Ann. For. Sci., 53: 605–613.

ČERNÝ, M., PAŘEZ, J., MALÍK, Z., 1996: Růstové a taxační tabulky hlavních dřevin České republiky. (*Growth and mensurational tables of main timber species of the Czech Republic*) Jílové u Prahy, IFER, 245 s.

KANTOR, P., KNOTT, R., 2000: Produkční potenciál a ekologická stabilita smíšených lesních porostů v pahorkatinách. II. Bukojedlový porost na svěžím stanovišti ŠLP Křtiny. (*Production potential and ecological stability of mixed forest stands in uplands. II. A beech-fir stand on the fresh site of the Training Forest Enterprise Křtiny*) Journal of Forest Science, 46, 2: 61.

KANTOR, P., KNOTT, R., MARTINÍK, A., 2001: Production potential and ecological stability of mixed forest stands in uplands. III. A single tree mixed stand with Douglas fir on a eutrophic site of the Křtiny Training Forest Enterprise. Journal of Forest Science, Vol. 47, No. 2, p. 45–59.

KLÍMA, S., 2004: Význam dubu zimního ve směsi modřínu a buku na ŠLP Křtiny. (*Importance of sessile oak in the mixture with larch and beech on sites operated by the Training Forest Enterprise Křtiny*) In: PEŇÁZ, J., MARTÍNEK, J.: Hlavní úkoly pěstování lesů na počátku 21. století. (*Main tasks of silviculture at the beginning of the 21st century*) MZLU, Brno, p. 159–172.

KOŠULIČ, M., 2010: Cesta k přírodě blízkému hospodářskému lesu. (*A Way to Near-Natural Commercial Forest*) Brno, FSC ČR, 449 s.

OSWALD, H., 1981: Résultats principaux des places d'expérience de chene du Centre National de Recherches Forestiéres. Revue Forestiére Francaise, 33: 65–85.

POLENO, Z., VACEK, S. et al., 2009: Pěstování lesů III. – Praktické postupy pěstování lesů. (*Silviculture III. – Practical procedures for growing forests*) Kostelec nad Černými lesy, Lesnická práce s. r. o., 951 s.

SANIGA, M., 2007. Pestovanie lesa. (*Silviculture*) Zvolen, TU Zvolen, 311 s.

SLODIČÁK, M., NOVÁK, J., 2007: Výchova lesních porostů hlavních hospodářských dřevin. (*Tending of the forest stands of main commercial timber species*) Lesnický průvodce, 4.

SVOBODA, P., 1955: Lesní dřeviny a jejich porosty – část II.. Praha, SZN, 573 s.

ŠTEFANČÍK, I., STRMEŇ, S., 2011: Vývoj dubového porostu postihnutého v minulosti hromadným hynutím. (*Development of the oak stand affected in the past by mass dieback)* Proceedings of Central European Silviculture – 12th International Conference, s. 103–111.

VYSKOT, M., 1958: Pěstění dubu. (*Growing oak*) Praha, SZN, 284 s.

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