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Production potential of Douglas fir in acid sites of Hůrky Training Forest District, Secondary Forestry School in Písek

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ABSTRACT: The study is a follow-up of the production potential of Douglas fir in mesotrophic sites of the Křtiny Training Forest Enterprise (TFE) (Journal of Forest Science, No. 7, 2008). Production parameters (height, dbh, volume) of Douglas fir are also evaluated, but in acid sites of the Hůrky Training Forest District, Secondary Forestry School in Písek in mature stands. In total, 17 mixed stands with the proportion of Douglas fir aged 88 to 121 years were assessed. Comparing 10 Douglas fir trees with 10 Norway spruce, Scots pine or European larch trees of the largest volume, higher and generally markedly higher production potential of the introduced Douglas fir was always found in all assessed stands. Groups where the volume of Douglas fir trees was two to three times higher than the volume of spruce, pine or larch were not an exception. For example, in stand 22B10, the mean volume of the 10 largest Douglas fir trees was 6.30 m^3 but the volume of spruce trees was only 1.93 m^3 and the volume of larch trees 2.25 m^3. Differences between the mensurational parameters of Douglas fir and spruce (or larch) assessed by the ANOVA test were statistically highly significant. At present (based on annual ring analyses), the volume increment of particular Douglas fir trees ranges at level of 0.06 to 0.10 m^3/year (i.e. about 0.6 m^3 to 1.0 m^3 per 10 years) in mature stands.

Keywords: Douglas fir; Norway spruce; Scots pine; European larch; production potential; acid sites

In the Journal of Forest Science, No. 7, 2008, a study *Production potential of Douglas fir in mesotrophic sites of TFE Křtiny* was published. The whole research project *Douglas fir – the introduced species in multifunctional and sustainable forest management* was briefly presented there. Simultaneously with the project treatment in mesotrophic sites of TFE Křtiny, the second series of research plots was established in the Hůrky Training Forest District of the Secondary Forestry School in Písek. However, there are nearly exclusively poor and acid sites of the 2nd and 3rd forest vegetation zones included in management sets of stands (MSS) 23 and 43. Thus, growing Douglas fir in Písek has more than a centennial tradition similarly like in Křtiny. At present, this species is recorded on more than 12% (!!) of the stand land (79 ha of reduced area) of the Písek TFE.

Data on the production potential of Douglas fir in its homeland, i.e. in the USA, in countries of Central Europe and in this country were discussed in the above-mentioned study published in the Journal of Forest Science.

In addition to basic generally operative data, extraordinarily high production of the species was analyzed and certified in mesotrophic sites (Hofman 1964; Burgbacher, Greve 1996; Huss 1996; Kantor et al. 2001). At the same time, however, the target proportion of the species is recommended

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even in acid sites, particularly in management sets of stands (MSS) 23 and 43 (Dolejský 2000; Šindelář 2003). Šika and Vinš (1980) assessed the production potential of Douglas fir on the basis of extensive investigations in the series of forest regions of the Czech Republic. According to their findings, the mean stand height of 60-year Douglas fir trees ranges at the level of about 37 m in mesotrophic sites, about 34 m in acid sites and only about 27 m in drying-up sites. Hrnčíř (1998) also drew similar conclusions showing in his thesis evidence of the lowest growth potential of the species in dry localities under conditions of the CR. On the other hand, in the region of Tábor, Šedivý (1990) reported the high growing stock of 60-year Douglas fir trees even in acid sites (the group of forest types 5K – growing stock: Douglas fir 1,020 m^3/ha; spruce 632 m^3/ha). Kadlec (1989) evaluated growth conditions of Douglas fir in the surroundings of Horažďovice in sites of management sets of stands 23, 43, 53, 45, 55 and 57 and compared its production with autochthonous species. In all MSS, Douglas fir showed the fastest growth and only in MSS 23, pine predominated Douglas fir. Douglas fir achieved the best results as compared with spruce and pine in MSS 43, where it showed double volume (1.28 m^3) compared to spruce (0.60 m^3) and pine (0.65 m^3).

In the last 5 years, considerable attention has been paid to problems of production possibilities of Douglas fir also in forestry-advanced countries of Europe. This introduced species is evaluated from various aspects, e.g. in papers of Lokow (2004), Rau (2005, 2006), Dong and Eder (2005), König (2006), Dietrich et al. (2006), etc.

Douglas fir in Hůrky Training Forest District

The Hůrky Training Forest District (TFD) serves as a special-purpose establishment of the Higher Secondary Forestry School and of Bedřich Schwarzenberg Secondary Forestry School in Písek. This TFD consists of an integrated complex of forests about 5 km south of Písek with a total area of 658 ha forest land (647 ha stand land). It is situated in cadastral areas of Smrkovice, Heřmaň, Selibov and Putim.

In the Hůrky TFD, only two forest vegetation zones are distinguished. On sunny drying up slopes, the beach/oak vegetation zone is situated (60 ha – 9%). However, the oak/beech forest vegetation zone totally dominates in the TFD (about 600 ha – 91%). In natural communities, beech and sessile oak with the admixture of linden predominated in the whole estate. In the proportion of trophic series, poor and acid sites wholly predominate (80% stand area). Gleyed and waterlogged sites account for 12% and mesotrophic sites for the remaining 8% area of the TFD.

Management conditions of the estate significantly changed at the end of the 18th and at the beginning of the 19th century when the autochthonous broadleaved stands of oak and beech were virtually totally converted to coniferous stands dominated by pine

Table 1. Development of the species composition in the Hůrky Training Forest District since 1830

Year	Spruce	Silver fir	Pine	Larch	**Other conifers***	Oak	Beech	Other broadleaves
1830	13.1	13.0	69.1	0.0	**0.0**	2.0	0.1	2.7
1877	16.0	9.3	63.2	2.2	**0.0**	4.9	0.0	4.4
1890	18.4	6.5	60.5	3.1	**0.0**	5.9	0.0	5.6
1910	24.2	6.7	66.6	0.0	**0.0**	1.7	0.6	0.2
1930	40.2	5.8	44.8	2.6	**0.0**	5.3	0.8	0.5
1940	46.2	5.6	35.2	2.7	**3.1**	5.3	0.7	1.2
1950	39.7	6.1	23.2	3.2	**4.6**	16.5	2.4	4.3
1970	37.1	4.8	34.2	2.4	**6.7**	10.1	2.3	2.4
1990	35.7	1.7	34.8	4.3	**9.2**	9.2	3.2	1.9
2000	42.8	2.3	20.1	4.0	**14.5**	9.5	4.9	1.9

*The proportion of Douglas fir is highest; in 2000, it accounted for 12.2% of the area (84% of the other coniferous species)

Table 2. The survey of growing stock and area of Douglas fir according to age classes in forest stands in the Hůrky Training Forest District

Age class	Number of stands	Growing stock (m^3)	Area of the species (ha)	Douglas fir growing stock (m^3/ha)
1 (1–10)	58	0	8.38	0.00
2 (11–20)	37	233	5.83	39.98
3 (21–30)	44	1,640	8.32	197.16
4 (31–40)	56	3,231	12.23	264.14
5 (41–50)	32	1,966	5.33	369.01
6 (51–60)	35	3,171	7.37	430.03
7 (61–70)	49	10,569	24.02	439.99
8 (71–80)	17	2,279	4.83	471.47
9 (81–90)	11	414	0.99	417.97
10 (91–100)	12	261	0.56	467.49
11 (101–110)	8	444	0.75	593.27
12 (111–120)	2	121	0.15	822.57
Total	**361**	**24,329**	**78.76**	**308.90**

monocultures. The species composition development in the Hůrky TFD from 1830 to the present time is given in Table 1. Thus, even at present, conifers predominate in the species composition, namely spruce nearly 43% and pine 20%. The third most widespread species is Douglas fir, the proportion of

Table 3. Characteristics of experimental stands

Stand	Group of stands	Age as of 1. 1. 2007	Management set of stands	Compared species
1A9	I	95	23	pine, oak
1B9		97		pine
12D9		97		pine
1C9a	II	88	43	oak
1C9b		88		pine
4C9		95		spruce, pine
4E9		86		spruce, larch
15E9		81		spruce
8C10	III	105	43	spruce
19C10		107		spruce
20B10		103		spruce, larch
22B10		102		spruce, pine
22C10		102		spruce
14A11	IV	108	43	spruce
15D12		121		spruce
15E11		117		beech
17C11		113		spruce, pine

which on 78.76 ha stand lands (12.2%) does not evidently show analogy in the Czech Republic on estates of similar size. The increase in its area (see Table 1) is given by its present natural and artificial regeneration as well as by the improvement of mensurational data at processing the last forest management plan (FMP) (as of 1 January 2000).

According to this FMP, in total 361 stand parts with the proportion of Douglas fir 1% and more are recorded in the Hůrky TFD. The total area of these stand parts amounts to 413.11 ha (63.9% stand land of the TFD). At the same time, the above-mentioned 78.76 ha (12.2% stand land) fall on Douglas fir.

Basic data on the proportion and growing stock of Douglas fir in particular age classes are given in Table 2. Thus, it is evident that Douglas fir occurs in the whole age spectrum. Similarly like in the Křtiny TFE, the occurrence of 58 stand parts of the 1st age class with Douglas fir (area 8.38 ha) in Hůrky TFD demonstrates the significant present position of this species in regeneration targets.

The majority of stands with Douglas fir were established there during the decade 1931–1940 (the present 7th age class). To a smaller extent, the species was, however, regularly grown there even before World War I; the oldest so far standing stand 15D12 was established in 1886.

In the Hůrky TFD, Douglas fir occurs in forest stands in all age classes predominantly in the position of individual trees or group admixtures. In 163 groups, it is recorded in a range from 1 to 10%. In 138 groups, the proportion of Douglas fir ranges between 11 and 50% and only in 40 groups, between 51 and 90%. As a monoculture, it occurs in 17 stands.

Methodology and characteristics of research stands

Methodology of determination of the production potential of Douglas fir in Hůrky TFD is identical with methodology represented in the Journal of Forest Science (No. 7, 2008), where production potentials of the species were assessed in mesotrophic sites of the Křtiny Training Forest Enterprise.

The list and registration of all stands from the forest management plan (as of 1. 1. 2000) for Hůrky TFD with the proportion of Douglas fir 1% and more served as a basic database to assess the production potential of Douglas fir. The list was compiled according to age classes and management sets of

Table 4. Mensurational parameters of the ten largest trees in stand 1A9 (age 95 years, management set of stands HS 23)

Douglas fir				Pine				Oak			
Tree No.	height (m)	dbh (cm)	volume (m^3)	tree No.	height (m)	dbh (cm)	volume (m^3)	tree No.	height (m)	dbh (cm)	volume (m^3)
1	35.0	65.3	5.23	1	32.0	55.1	3.32	1	25.5	59.6	3.90
2	37.0	63.1	5.23	2	29.0	48.4	2.30	2	22.0	52.2	2.53
3	35.0	59.9	4.54	3	25.5	47.8	2.04	3	24.5	47.8	2.36
4	36.5	57.6	4.44	4	27.0	40.1	1.49	4	26.5	43.9	2.12
5	36.0	57.6	4.38	5	24.0	42.0	1.47	5	26.0	43.0	1.99
6	36.5	55.7	4.18	6	25.0	39.8	1.38	6	24.0	42.4	1.75
7	37.5	53.5	4.04	7	23.5	41.4	1.37	7	23.0	41.1	1.60
8	35.0	54.5	3.76	8	25.0	39.5	1.32	8	25.5	39.2	1.59
9	34.5	53.8	3.71	9	28.0	36.9	1.32	9	25.0	39.2	1.56
10	35.0	52.5	3.64	10	24.0	39.2	1.27	10	24.0	38.9	1.50
Mean	35.8	57.4	4.32	mean	26.3	43.0	1.73	mean	24.6	44.7	2.09

Statistical parameters of the largest trees

	Mean	Median	Lower quartile	Upper quartile	Standard deviation
Dgl (volume m^3)	4.32	4.28	3.76	4.54	0.57
Pine (volume m^3)	1.73	1.43	1.32	2.04	0.66
Oak (volume m^3)	2.09	1.87	1.59	2.36	0.73

stands. As mentioned above, there are 361 stands in the given estate and the reduced area of Douglas fir amounts to 78.76 ha.

In the present study, the oldest mature stands in the 9th to the 12th age class are evaluated. In total, 17 stands were assessed, which corresponded to methodical requirements for research surveys. Their list is given in Table 3.

The stands were classified according to age and management sets of stands into 4 groups: in the 9th age class, three stands were evaluated in MSS 23 and five stands in MSS 43. In the 10th age class, five stands were assessed in MSS 43 and in the 11th age class, four stands again in MSS 43. Demonstrably, stand 15D12 appears to be there the oldest evaluated stand with the registered proportion of Douglas fir. The stand was established in 1886 (as of 1. 1. 2008 – age 122 years).

In each of the stands, 10 Douglas fir trees with the highest dbh were marked and recorded. At the same time, height was measured in each of the trees. Finally, the volume of trees was calculated according to actual volume tables (tables of the Forest Management Institute for the stem volume over bark of silver fir). The same method was used, i.e. marking in the stand, recording and measuring volumes of trees with the highest dbh, to determine the production potential of other species of assessed stands: spruce, pine, larch and sessile oak. Only trees within stand parts were included in the evaluation. On the contrary, edge trees, trees along roads, cleared boundary lines, corridors, etc. were excluded from the evaluation. In the following text, results of studies from 4 stands are compiled in simple tables. Thus, one characteristic stand is represented from each of the groups.

The significance of differences in the production potential (volume in m^3) among the particular species was statistically evaluated by the ANOVA single-factor test.

Within the study of the Douglas fir production potential, the diameter increment of three sample trees was retrospectively analyzed in stand 18D8 by means of computer-based image analysis using OSM and PAST programs. Respective increment cores were scanned immediately after sampling (excluding the effect of shrinkage) and subsequently processed only in a digital form. The volume increment was then calculated from the diameter increment and heights derived from the yield tables.

Table 5. Mensurational parameters of the ten largest trees in stand 4C9 (age 95 years, MSS 43)

Douglas fir				Spruce				Pine			
Tree No.	height (m)	dbh (cm)	volume (m^3)	tree No.	height (m)	dbh (cm)	volume (m^3)	tree No.	height (m)	dbh (cm)	volume (m^3)
1	38.0	65.0	5.68	1	34.5	38.2	1.81	1	33.5	42.0	2.02
2	38.0	55.4	4.11	2	34.0	36.9	1.70	2	33.5	39.2	1.75
3	37.0	54.1	3.98	3	33.5	36.3	1.59	3	33.0	39.5	1.73
4	35.5	53.2	3.69	4	32.0	34.7	1.45	4	32.5	39.2	1.70
5	33.5	50.0	3.12	5	33.0	33.8	1.41	5	33.0	38.2	1.64
6	34.0	48.7	3.06	6	34.0	33.4	1.38	6	32.0	36.6	1.51
7	33.0	47.8	2.85	7	32.0	33.8	1.37	7	31.5	36.0	1.40
8	34.0	47.1	2.84	8	32.0	33.8	1.37	8	31.0	35.0	1.30
9	32.5	45.2	2.50	9	31.5	33.4	1.28	9	32.5	34.1	1.29
10	33.0	43.9	2.44	10	31.5	31.5	1.21	10	32.0	34.4	1.27
Mean	34.9	51.1	3.43	mean	32.8	34.6	1.46	mean	32.45	37.4	1.56

Statistical parameters of the largest trees

	Mean	Median	Lower quartile	Upper quartile	Standard deviation
Dgl (volume m^3)	3.43	3.09	2.84	3.98	0.98
Spruce (volume m^3)	1.46	1.40	1.37	1.59	0.19
Pine (volume m^3)	1.56	1.58	1.30	1.73	0.25

Table 6. Mensurational parameters of the ten largest trees in stand 22B10 (age 102 years, MSS 43)

Douglas fir				Spruce				Larch			
Tree No.	height (m)	dbh (cm)	volume (m^3)	tree No.	height (m)	dbh (cm)	volume (m^3)	tree No.	height (m)	dbh (cm)	volume (m^3)
1	40.0	80.9	8.69	1	31.0	49.0	2.51	1	33.0	59.2	3.37
2	43.0	75.8	8.43	2	34.0	40.8	2.03	2	34.0	50.0	2.76
3	41.0	73.6	7.68	3	32.0	42.4	1.99	3	35.5	42.7	2.37
4	41.5	72.6	7.58	4	32.5	41.1	1.94	4	34.0	42.7	2.21
5	40.5	69.1	6.71	5	33.5	40.1	1.92	5	35.0	41.4	2.16
6	39.0	60.8	5.32	6	34.0	38.9	1.86	6	33.5	42.0	2.09
7	40.0	59.2	5.01	7	33.0	39.2	1.81	7	34.0	41.4	2.06
8	38.5	58.0	4.68	8	32.5	38.5	1.78	8	32.0	41.1	1.89
9	37.5	58.0	4.56	9	32.0	38.5	1.76	9	34.0	37.6	1.84
10	39.0	54.8	4.33	10	31.5	38.9	1.73	10	30.0	41.7	1.77
Mean	40.0	66.3	6.30	mean	32.6	40.7	1.93	mean	33.5	44.0	2.25

Statistical parameters of the largest trees

	Mean	Median	Lower quartile	Upper quartile	Standard deviation
Dgl (volume m^3)	6.30	6.02	4.68	7.68	1.70
Spruce (volume m^3)	1.93	1.89	1.78	1.99	0.23
Larch (volume m^3)	2.25	2.13	1.89	2.37	0.49

Table 7. Mensurational parameters of the ten largest trees in stand 17C11 (age 113 years, MSS 43)

Douglas fir				Pine				Spruce			
Tree No.	height (m)	dbh (cm)	volume (m^3)	tree No.	height (m)	dbh (cm)	volume (m^3)	tree No.	height (m)	dbh (cm)	volume (m^3)
1	43.5	73.9	8.14	1	36.5	51.9	3.36	1	38.5	61.5	4.45
2	40.0	75.2	7.67	2	31.0	50.3	2.66	2	34.0	51.9	3.03
3	41.5	69.7	7.04	3	34.5	45.9	2.50	3	31.5	52.9	2.91
4	43.0	68.5	6.95	4	33.0	46.2	2.38	4	34.5	44.6	2.43
5	42.0	58.6	5.26	5	31.5	45.5	2.29	5	34.0	44.6	2.39
6	43.0	58.3	5.22	6	31.0	43.9	2.06	6	33.0	44.6	2.32
7	42.0	57.3	4.96	7	34.0	42.4	2.05	7	34.0	43.9	2.30
8	40.5	58.0	4.92	8	34.0	41.7	2.05	8	32.5	43.6	2.20
9	42.0	55.1	4.67	9	32.0	42.0	1.93	9	33.5	42.7	2.18
10	39.5	56.4	4.52	10	33.0	41.4	1.90	10	32.0	44.3	2.16
Mean	41.7	63.1	5.94	mean	33.1	45.1	2.32	mean	33.8	47.5	2.64

Statistical parameters of the largest trees

	Mean	Median	Lower quartile	Upper quartile	Standard deviation
Dgl (volume m^3)	5.94	5.24	4.92	7.04	1.36
Spruce (volume m^3)	2.64	2.36	2.20	2.91	0.70
Pine (volume m^3)	2.32	2.17	2.05	2.50	0.44

RESULTS AND DISCUSSION

Results of studies are processed similarly like in the Křtiny Training Forest Enterprise. Basic mensurational data of the largest Douglas fir trees and largest autochthonous trees (spruce, pine, larch, sessile oak) in assessed stands are given in Tables 4 to 7. Very interesting findings were already noted in the first represented stand 1A9 (age 95 years – see Table 4). The stand is situated on a drying up SW slope. Nevertheless, the height of the largest Douglas fir trees ranged between 34.5 and 37.5 m, which is on average by nearly 10 m (!!) more than in pine.

Similarly, markedly higher dbh together with the height of Douglas fir trees manifested itself in their volume. This volume ranged from 3.64 m^3 to 5.23 m^3. Particularly from the aspect of site conditions (acid, drying up sites, shallow soils very poor in minerals, total annual precipitation 500 to 600 mm) as well as stand age, it documents a remarkable potential of the species, which is on average double in comparison with pine.

Data on production parameters of oak were included in Table 4 particularly because the mixture of Douglas fir with sessile oak, which is uncommon elsewhere, is rather common on southern, western and south-western aspects of the Hůrky TFD. Nevertheless, the comparison of oak ad Douglas fir is not commented more closely here because of quite different biological and growth characteristics of both species. Somewhat lower absolute production parameters were noted in a stand marked 4C9 in MSS 43 (see Table 5). Nevertheless, even here, the volume of the largest Douglas fir trees (on average 3.43 m^3) is more than twofold than in spruce (on average 1.46 m^3) or pine (1.56 m^3). Extremely high production potentials of Douglas fir are shown by 102-year stand 22B10 again in MSS 43 (see Table 6). The largest Douglas fir trees show there on average a volume of 6.30 m^3 at a mean height of 40 m. It is 3.3 times more than the volume of spruce trees and 2.8 times more than the volume of the largest larch trees.

Representative data from the oldest group of stands are given in Table 7. Similarly like in all assessed stands all evaluated parameters (height, dbh, volume) in Douglas fir are higher than in compared conifers, namely in spruce and pine.

Table 8. Mean parameters of the ten largest conifers in assessed stands of the 9th to the 12th age class in the Hůrky Training Forest District

Stand	Douglas fir			Spruce			Pine			Larch		
	height (m)	dbh (cm)	volume (m^3)	height (m)	dbh (cm)	volume (m^3)	height (m)	dbh (cm)	volume (m^3)	height (m)	dbh (cm)	volume (m^3)
1A9	35.8	57.4	4.32				26.3	43.0	1.73			
1B9	35.6	57.8	4.33				30.1	52.2	2.82			
12D9	38.1	53.9	4.11				32.0	43.8	2.11			
1C9a	41.8	59.4	5.41									
1C9b	34.3	51.8	3.42				26.6	38.2	1.35			
4C9	34.9	51.1	3.43	32.8	34.6	1.46	32.5	37.4	1.56			
4E9	36.7	54.4	4.19	32.7	40.1	1.89				35.1	39.8	2.08
15E9	40.0	55.5	4.53	35.6	49.6	2.96						
22B10	36.4	66.3	6.30	32.6	40.7	1.93				33.5	44.0	2.25
20B10	39.8	64.6	6.03	34.3	46.5	2.56	34.4	51.4	3.12			
22C10	35.2	48.4	3.19	34.1	39.3	1.91						
19C10	38.4	53.2	4.07	35.2	55.4	3.53						
8C10	37.5	65.1	5.70	31.9	44.9	2.25						
14A11	44.5	73.1	8.17	37.3	62.6	4.57						
17C11	41.7	63.1	5.94	33.8	47.5	2.64	33.1	45.1	2.32			
15E11	46.7	73.3	8.54									
15D12	44.4	77.6	8.98	39.9	59.4	4.42						

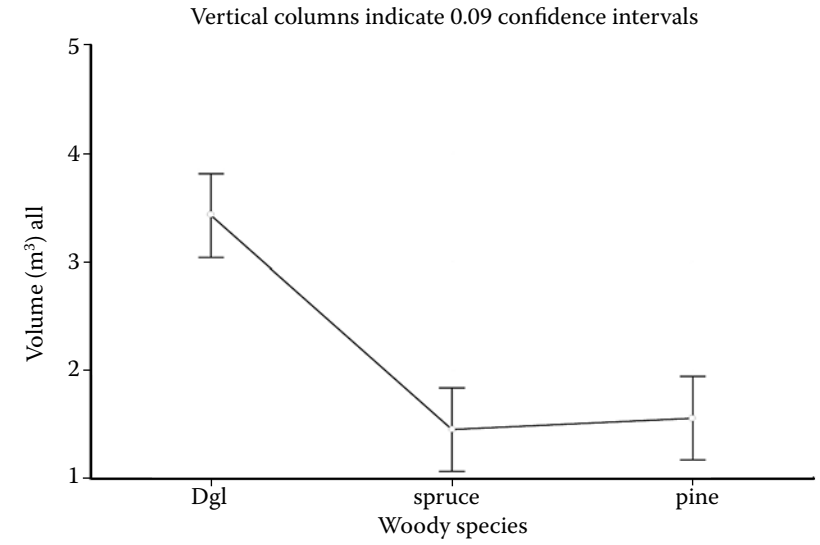

Fig. 1. The significance of differences in the production potential of Douglas fir, Norway spruce and Scots pine (single-factor ANOVA test) in the management set of stands (MSS) 43 (*y*-axis – mean stem volume of sample trees)

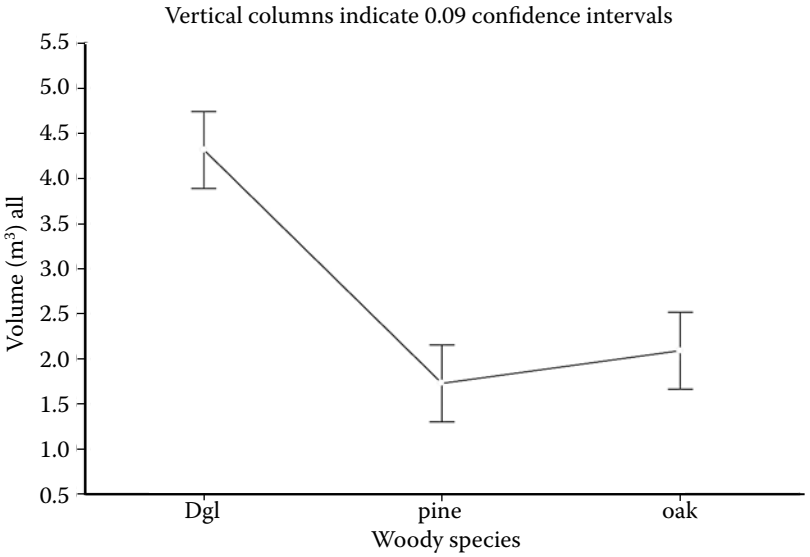

Fig. 2. The significance of differences in the production potential of Douglas fir, Scots pine and sessile oak (single-factor ANOVA test) in the management set of stands (MSS) 23 (*y*-axis – mean stem volume of sample trees)

This unambiguous finding results also from Tables 8 and 9, where partly mean values are compiled from all 17 stands under evaluation and partly values of the 10 absolutely largest trees in the given age interval in the Hůrky TFD.

Determined differences in mensurational parameters of Douglas fir on the one hand and spruce, pine or oak on the other hand compared by a single-factor test ANOVA were (without exception) naturally statistically highly significant. By contrast, the same test did not confirm any significant differences among production potentials of spruce, pine and oak (Figs. 1 and 2).

The high production potential of Douglas fir even in acid sites of lower vegetation zones was proved by the retrospective analysis of diameter increment in three sample trees in stand 18D8 (see Fig. 3). At the age of 80 years, the evaluated sample trees showed the following parameters:

sample tree 1 height 34 m dbh 50.5 cm volume 3.06 m^3,
sample tree 2 height 34 m dbh 54.5 cm volume 3.42 m^3,
sample tree 3 height 37 m dbh 61.0 cm volume 4.42 m^3.

The course of increments shows an initially usual downward trend – from about 10 mm/year at the age of 20 years to about 6 mm/year at the age of 45 years. Evidently due to tending measures, the diameter increment does not decrease even in the next period oscillating from 4 to 14 mm/year about the mean value of 7–8 mm/year in all three sample trees.

After conversion, the current volume increment of the largest Douglas fir trees in acid sites of the Hůrky Training Forest District amounts to about 0.06 to 0.10 m^3/year at the age of 50 to 80 years. In other words, these Douglas fir trees increase, even at present, their volume by 0.6–1.0 m^3 (see Table 10)

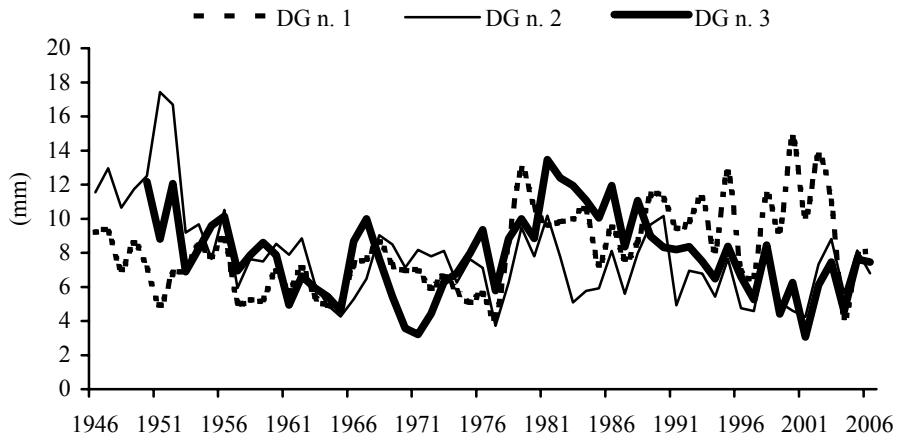

Fig. 3. Annual ring analysis of the development of 3 sample trees of Douglas fir in stand 18D8 (*y*-axis – annual diameter increment)

every 10 years. Wolf (1998) and Bušina (2006) also reported extraordinary production possibilities of Douglas fir in acid sites of the Hůrky Training Forest District. A young unmixed Douglas fir stand showed the total volume production of 619 m^3/ha (!!) at the age of 31 years. In the period of 1993 to 1997, the stand increased its standing volume even by 23 m^3/ha (Wolf 1998). According to all parameters, it concerns a stand which markedly exceeds the 1st site class of valid growth tables at the given age. Also in other evaluated stands in poor acid sites, periodic current increment amounted to 21 m^3/ha/year in the last 8 years (Wolf 1998).

In his Ph.D. thesis Bušina (2006) also evaluated the basic mensurational parameters of 219 Douglas fir trees aged 65 to 121 years growing at the same estate. The volume of the youngest and largest Douglas fir trees exceeded 5.00 m^3. The oldest and largest Douglas fir trees showed the volume between 10.44 and 14.3 m^3 and the periodic volume increment amounted even to 0.28 m^3/year in the last 30 years.

SUMMARY AND CONCLUSION

In connection with the importance of introduced species, the Hůrky Training Forest District of the Secondary Forestry School in Písek shows quite a specific position. With the proportion of Douglas fir amounting to 12.2% of the area it can serve as an exemplary area for growing the species. Moreover, there is a number of data on tending programmes of Douglas fir (Wolf 1998) and its production potential (Bušina 2006). Douglas fir is traditionally grown there in mixed, as a rule individually mixed stands. In addition to simple mixtures of Douglas fir with spruce, mixed stands with a rich spectrum of

Table 9. The largest trees in Hůrky TFD in assessed stands of the 9th to the 12th age class (MSS 23, 43)

Order	Douglas fir		Spruce		Pine		Larch	
	stand	volume (m^3)	stand	volume (m^3)	stand	volume (m^3)	stand	volume (m^3)
1	15D12	15.23	15D12	7.31	20B10	3.67	22B10	3.37
2	14A11	12.05	15A11	7.24	20B10	3.61	4E9	2.79
3	15E11	10.34	15A11	5.29	1B9	3.47	22B10	2.76
4	15E11	10.11	15D12	5.11	20B10	3.45	22B10	2.37
5	15D12	10.01	15A11	5.03	20B10	3.36	4E9	2.33
6	15D12	9.95	15A11	4.51	17C11	3.36	4E9	2.24
7	15D12	9.66	15A11	4.51	1B9	3.33	22B10	2.21
8	15D12	9.57	19C10	4.47	1B9	3.20	22B10	2.16
9	15D12	9.55	19C10	4.37	20B10	3.20	4E9	2.12
10	14A11	9.31	15D12	4.27	20B10	3.03	22B10	2.09
Mean		**10.58**		**5.21**		**3.37**		**2.44**

Table 10. Retrospective analysis of the development of one Douglas fir sample tree in stand 18D8

Age	Height (m)	dbh (cm)	Volume (m^3)	Diameter increment (mm)	Volume increment (m^3)
80	34	50.5	3.06	44.88	0.53
75	33	46.0	2.53	52.20	0.53
70	31.5	40.8	2.00	48.86	0.48
65	30	35.9	1.52	48.30	0.43
60	28	31.1	1.09	47.10	0.35
55	26.5	26.4	0.74	46.10	0.23
50	25	21.8	0.51	28.98	0.14
45	23.5	18.9	0.37	37.44	0.16
40	21.5	15.1	0.21	29.82	0.08
35	20	12.1	0.13	28.28	0.08
30	18	9.3	0.05	–	–

5 to 8 species are not exceptions. Thus, the unusual mixture of Douglas fir with sessile oak creates a specific group.

Similarly like in mesotrophic sites of Křtiny TFE, the exceptionally high production potential of this introduced species as compared with autochthonous commercial conifers has been proved also here in the 9th to 12th age classes in acid sites. It is also documented by Tables 8 and 9, where mean values are given from the 17 assessed stands as well as basic mensurational parameters of the largest trees from all evaluated stands.

The volume of the 10 largest Douglas fir trees amounted there on average to 10.58 m^3, which was a value comparable with mesotrophic sites in TFE Křtiny (12.47 m^3). The largest Douglas fir tree in the Hůrky TFD (15.23 m^3) has even 1.5 m^3 higher volume than the largest Douglas fir tree in mesotrophic sites of TFE Křtiny (13.72 m^3).

To assess the production potential of Douglas fir, the annual ring analysis of three sample trees from stand 18D8 (age 80 years) is also important. Even at this age, the diameter increment of the largest Douglas fir trees oscillates about a mean value of ± 7–8 mm/year, which represents a current volume increment of 0.06–0.10 m^3/year.

In conclusion, it is possible to state that similarly like in nutrient-rich soils, also in acid sites of the 2nd and 3rd forest vegetation zones, the exceptionally high production potential of Douglas fir has been proved. Thus, the production potential of this introduced species is also here twofold as compared with autochthonous conifers, i.e. spruce and pine.

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Produkční potenciál douglasky tisolisté na kyselých stanovištích Školního polesí Hůrky Střední lesnické školy Písek

ABSTRAKT: Studie navazuje na hodnocení produkčního potenciálu douglasky tisolisté na živných stanovištích ŠLP Křtiny (Journal of Forest Science, č. 7, 2008). Rovněž zde jsou hodnoceny produkční parametry (výška, $d_{1,3}$, objem) douglasky tisolisté, ale na kyselých stanovištích Školního polesí Hůrky Střední lesnické školy Písek v porostech mýtného věku. Celkem bylo posuzováno 17 smíšených porostů s evidovaným zastoupením douglasky ve věku 88 až 121 let. Srovnáním deseti nejobjemnějších douglasek s deseti nejhmotnatějšími smrky, borovicemi, resp. modříny byl bez výjimky ve všech hodnocených porostech zjištěn vyšší, zpravidla výrazně vyšší produkční potenciál introdukované douglasky. Výjimkou nebyly skupiny, kde byl objem douglasek dvakrát až třikrát větší než objem smrků nebo modřínů. V porostu 22B10 byl např. zaznamenán střední objem deseti nejobjemnějších douglasek 6,30 m^3, ale objem smrků pouze 1,93 m^3 a objem modřínů 2,25 m^3. Zjištěné rozdíly dendrometrických parametrů douglasky na jedné a smrku, resp. modřínu na druhé straně, srovnávané testem ANOVA, byly statisticky vysoce průkazné. Z letokruhových analýz souběžně vyplynulo, že v současné době se pohybuje v dospělých porostech objemový přírůst jednotlivých douglasek na úrovni 0,06 až 0,10 m^3/rok (tj. ca 0,6 m^3 až 1,0 m^3 každých 10 let).

Klíčová slova: douglaska tisolistá; smrk; borovice; modřín; produkční potenciál; kyselá stanoviště

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