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Assessing the growth of *Picea omorika* [Panč.] Purkyně in the Masaryk Forest Training Forest Enterprise at Křtiny

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ABSTRACT: Plantations of Serbian spruce (*Picea omorika* [Panč.] Purkyně) reach an age over 70 years at the Masaryk Forest Training Forest Enterprise (TFE) at Křtiny. They occur at different sites of the TFE, which is situated north of Brno between Blansko, Jedovnice and Brno in the Czech Republic. The paper presents an assessment of primary mensurational values (diameter at breast height d.b.h., height h, Derbholz volume m^3), fertility, mortality and general health condition. The present registered number of Serbian spruce trees is 425 (from originally 750 individuals) in 25 localities and 12 GFT (groups of forest types). A comparison of Serbian spruce mensurational data with growth tables indicated that Serbian spruce on GFT 4K makes up for the tabular mean values of Norway spruce (*Picea abies* [L.] Karst.) in yield class +1.

Keywords: growth assessment; localities; introduced tree species; Serbian spruce; group of forest types

At the beginning of the last century, Serbian spruce (*Picea omorika* [Panč.] Purkyně) was known only as a rare tree species of collections. It was first found as late as in 1855 and described only 22 years later. In the following 50 years it was planted only into collections of introduced species popular at that time. The first experimental plots started to be planted in connection with the increasing demand of wood mass in order to assess the species production potential.

The first extensive experimental plantations of introduced species including Serbian spruce were coming into existence also in the TFE territory. At the present time, the stands reach the felling maturity common in Central Europe and a time has arrived to decide on their future existence.

This contribution is a part of doctoral thesis dealing with the inventory of *Picea* and *Abies* genera species, assessment of their growth, development, health condition and possibilities of reproduction in the TFE territory or their use in Czech forestry.

MATERIAL

THE MASARYK FOREST TRAINING FOREST ENTERPRISE KŘTINY – NATURAL CONDITIONS

The Masaryk Forest Training Forest Enterprise Křtiny (TFE) is one of the oldest training forest enterprises in the Czech Republic. It was founded in 1922 its area being 7,903 ha. The present TFE area is 10,578 ha. Its location was chosen with respect to diverse abiotic conditions in the territory. TFE is situated north of Brno, in a triangle formed by the municipalities Blansko and Jedovnice and the town of Brno. The complex of forests is only sporadically broken by farmlands and several small villages.

TFE can be found at an altitude of 210–575 m, its geological and soil conditions being very diverse, av. annual temperature ranging from 6.5–8.4°C and av. annual precipitation being 550–700 mm.

Plantations of many introduced tree species mainly from North America originate from the times of the previous owner of the estate, Duke Liechtenstein. Exotic or introduced species can be seen at many places. Most of the collection species can be seen in Křtiny Arboretum, which was founded by Prof. A. Bayer, Dean of the Faculty of Forestry at the then University of Agriculture and professor at the Department of Dendrology. Another large collection, this time mainly of coniferous species, is in Řícmanice Arboretum. Other plantations are scattered across the whole TFE on decorative forest glades and experimental plots.

Most tree species existing at the Training Forest Enterprise were planted in three periods of time. The oldest period is the 2nd half of the 19th century and the beginning of the 20th century, which was a period when the Adamov forests were managed by their original owner – Duke

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Liechtenstein. The second period started in the 1930s (1924–1969) after the Adamov forests had been taken over by the Faculty of Forestry as a special-purpose facility. Most plantations of grown-up Serbian spruce specimens in the arboreta and on the decorative glades originate from the beginning of this period. The third period started in the 1970s when files of all exotic species from older plantations were launched and has been lasting until the present time (SOUČEK 1985).

SERBIAN SPRUCE *PICEA OMORIKA* [PANČ.] PURKYNĚ

Serbian spruce was first found by Prof. J. Pančič (1814–1888) in western Serbia in 1855, who described it as the Serbian spruce of Pančič in 1887 after having had studied the species and visited its sites (KRÜSSMANN 1972; VIDAKOVIĆ 1991).

Serbian spruce is an endemic species of the Balkan Peninsula that survived as one of Tertiary relics. Its close relatives – *P. omoricoides* and *P. paleoomorika* – once used to take up an extensive area from northern Europe up to Asia. Its nearest living relatives are *Picea sitchensis* (North America) and *Picea ajanensis* (eastern Asia) (PILÁT 1964; VIDAKOVIĆ 1991).

The present natural range of Serbian spruce is strictly limited to the territory of Bosnia and Herzegovina in the Dinar Mts. north of Višegrád in the middle reach of the Drina River on mountain tops in the districts of Ustiprača and Foča. The localities of isle character are on limestone outcrops, on slopes with the northern and NE aspect, at altitudes ranging from 300–1,700 m (PILÁT 1964; KLIKA 1953; VIDAKOVIĆ 1991) with the bedrock being formed by limestones and rankers on serpentinites (JOVANOVIĆ 1985; PILÁT 1964).

The species either forms groups or grows in mixtures with other species such as *Fagus sylvatica*, *Picea abies*, *Pinus nigra*, *Pinus sylvestris*, *Abies alba* and *Ostrya carpinifolia* (JOVANOVIĆ 1985; PILÁT 1964; VIDAKOVIĆ 1991), having been described in *Piceetum omorikae* Treg., *Abieto-Piceetum illyricum piceetosum omorikae* Fuk. and other phytocoenoses (JOVANOVIĆ 1985).

In its home country, Serbian spruce is a tree reaching a height of 50 m (30 m in the Czech Republic), with a conspicuously narrow and slender conical crown with the typical pyramidal appearance and a relatively slim stem whose av. diameter at a height of 40 m is ranging from 38–70 cm (PILÁT 1964). Branches are rather short (0.5–2.0 m), almost horizontally set-off, more rising toward the top and declining at the bottom. Bark is thin, reddish-brown, peeling in round scales (JOVANOVIĆ 1982; KLIKA 1953; KOBLÍŽEK 2000; PILÁT 1964; POKORNÝ 1981; VIDAKOVIĆ 1991). Ones of the first introductions outside the place of finding in Europe are plantations in England: the oldest one at all with h = 19 m, d.b.h . = 27 cm (1970) (Kew Garden, London, 1889) and the largest ones with h = 27 m, d.b.h. = 60 cm (1970) and h = 26 m, d.b.h. = 61 cm (1970) (Murthy Castle, 1897) (MITCHELL 1975). The first introductions in Belgium are as follows: the oldest one with h = 28 m, d.b.h. = 46 cm and the largest one with h = 34 m 42 cm, the one with the greatest d.b.h. = 55 cm with no height figure (BAUDOIN 1992).

Originating from the South, it does very well also in Central and Northern Europe today. The species was introduced in Europe after 1880 and the first registered introductions in Bohemia are from Prague, Krč (1906) and from Jezeří (1910) (SVOBODA 1976). The oldest individuals in the Czech Republic can be found in a park at Chlum near Třeboň, at Konopiště, and in the Prague Royal Game Enclosure (POKORNÝ 1981), in Žehušice, and a row of grown-up trees at Bílá Lhota near Litovel (PILÁT 1964).

Serbian spruce is a frost-resistant species in our country. Unlike other species, it suffers neither from early or late frosts nor from snow damage at higher altitudes as Norway spruce (*Picea abies* [L.] Karst.); being resistant to urban environment, it is tolerant to the climate of large cities. Its requirements for soil and site are modest. It does best in fresh moist soil, humid air and cold environment. Its plantations on seasoning localities where other species (*Picea abies, Pinus sylvestris*) would just dwarf grow relatively well, too (HOLUBČÍK 1968; MÁLEK 1984; PILÁT 1964; POKORNÝ 1981; ÚRADNÍČEK, CHMELAŘ 1995).

The height growth of Serbian spruce is rather fast; the species reaches 3–4 m, 5–6 m, 7–8 m and about 12 m at the age of 10, 15, 20 and 30 years, respectively (POKORNÝ 1981). Other authors claim its height to be ranging from 1.5–2 m and from 8–10 m at the age of 10 and 20 years, resp. The greatest growth rate is recorded between 20–30 years of age; Serbian spruce grows somewhat faster than Norway spruce (KLIKA 1953; PILÁT 1964). The growth of Norway spruce is compensated for later but the species' volume production is usually lower due to the open canopy (HOLUBČÍK 1968).

SERBIAN SPRUCE AT THE MASARYK FOREST TRAINING FOREST ENTERPRISE AT KŘTINY

Seed of Serbian spruce was sown from 1928 for several years being supplied by foresters from Yugoslavia attending an excursion to the then forest enterprise. In autumn 1934, the stock of 4-year transplants, 2-year transplants and 1-year seedlings amounted to 390, 830 and 2,420, resp. (SOUČEK 1985).

The oldest plants were planted on aesthetic glades in 1934 and 1935. Younger plants were later placed into various stands most of them being planted in the forest districts of Habrůvka (Locality 28), Babice (Locality 59) and Bílovice (Locality 67 in the present Řícmanice Arboretum). The plantations yielded a considerable amount of fructifying trees with the rich crop of seeds. A whole group growing in the Habrůvka forest district has been certified for the collection of seed, which serves to raise new generations. As many as 600 3-year plants were for example planted in Stand $48b_2$ in the Bílovice forest dis-

Table 1. Measurement files – classification by age

File	Division into files				
	S1	S2	S3	S4	S5
Age interval (years)	29–37	38–46	47–55	56–64	65–73
Years of measurements	1968–1971	1975–1978	1982–1983	1993–1994	1998–2001

trict in 1980. Both the older and the newer plantations exhibit good growth. Natural self-seeding is considerable (e.g. Řícmanice Arboretum, the former Habrůvka forest district, Locality 67) (SOUČEK 1985).

METHODS

Field measurements were made in 1999–2001 in Serbian spruce plantations on decorative glades, in arboreta and on experimental plots across the entire TFE. Parameters measured by using standard mensurational procedures were d.b.h. (cm) and tree height (m), health condition (abiotic damage and infestation by major forest pests or damage by game), number of stems, fertility at the time of measurement, and occurrence of natural regeneration.

Basic information on the TFE Serbian spruce plantations was obtained from TRUHLÁŘ et al. (1987). This work contains the first synoptic measurements of introduced species at the Training Forest Enterprise with the first d.b.h. measurements made at 30–40 years of tree age. The second measurements were made after 7–9 years and included d.b.h. and tree height. Other data were drawn from similar works (MÁLEK 1984; ROZKOPAL 1994; KRÁL 1999). All available data were revised in order to put them together and eliminate errors. All field data and data from previous works were currently stored in a database.

There are about 25 localities at the TFE with Serbian spruce plantations originating from the 1930s. Sites are considerably varied in both ecological and soil conditions, aspect, and in altitudes and hence rainfall amounts. A model of groups of forest types (GFT) was therefore chosen for the comparison of Serbian spruce growth, which made it possible to take into account all these factors and to make a comparison of Serbian spruce with the growth of domestic Czech tree species, Norway spruce.

The measurements were sorted out into 5 data files with the 9-year interval starting at the age of 29 years. This classification enables to gather irregular measurements into tree groups of approximately same age and size.

Measurement values of trees below d.b.h. = 7 cm were discarded from the database, the trees being mentioned as dead standing trees or living stubs.

The generated GFT data files were subjected to a retrospective evaluation onto a minimum sample size for the prescribed standard deviation. Independent, random variables originated from the normal distribution. The minimum sampling size was defined as follows:

$$n = \frac{g_2(x) - 1}{4\,\delta^2(s)} + 1$$

where: g_2 – the pointedness of sampling distribution,
$\delta(s)$ – the relative error of standard deviation.

Sampling pointedness was calculated by using the following formula:

$$g_2 = \frac{\sum_{j=1}^{N} (x_j - x)^4}{NS^4} - 3$$

Regarding the fact that the number of trees fulfilling the condition of planting year being 1928 or 1934 is finite and permanently diminishing, it was impossible to assume the usual size of standard deviation relative error being 5% and the error computed retrospectively from the data was often higher. The relative errors of standard deviation are presented for the most extensive data files from the respective GFT.

Basic statistic characteristics were assessed by using the Adstat 2.0 programme. The selected GFT were tested on the incidence of deviated objects. The objects were discarded after having been weighted as subdominant trees with no increment in 30 years. A test of distribution normality resulted in the normality being demonstrated for most data files, in five illustrated cases it was necessary to carry out a simple power transformation (to modify the data file in terms of slantness and pointedness as related to normal distribution) and to use the standard deviation and arithmetic mean values modified by it.

Volume of Derbholz over bark was measured in all individuals according to the ÚLT volume tables (1951) for spruce (all age classes). This paper presents the values of Derbholz over bark in m^3.

Collection of cones from average trees was made twice in Locality 67-Řícmanice Arboretum, viz in October 1999 and in October 2001. The cones were at all times weighed and measured in November. Basic seed characteristics according to ČSN 48 1211 were determined after the cones had been dried at a temperature of 50°C.

RESULTS AND DISCUSSION

There are 750 tree records of which 653 individuals were registered as at 1970 when the first general recording ended. The remaining 97 trees were either overlooked or did not reach the d.b.h. of 7 cm. The present comprehensive inventory included a total of 425 living trees of which 408 were used for the assessment.

When evaluating the data the author found a discrepancy in two localities between the registered date of planting and the actual growth condition (Localities 48 and 67).

Table 2. Average informative data of the entire data file without resolution of GFT

	File 1	File 2	File 3	File 4	File 5
Average age (years)	35.1	38.5	49.0	59.9	66.8
Number (pcs)	653	645	497	165	408
Average diameter (cm)	16.73	17.98	22.15	29.83	28.93
Average height (m)		14.26	17.89	22.01	22.52

The year of planting was specified after a comparison with localities in the same GFT, confrontation of all available data with planting dates and field determination of actual age of the plantations.

The data file contents are presented in Table 2. These data are arithmetic means of all available data in all GFT with Serbian spruce. Data File 4 whose average diameter is slightly higher due to the fact that the inventory was not made in all GFT and localities was set up with regard to irregular intervals of the measurements.

Average diameter at breast height d.b.h. in Data File 2 was 18.0 cm (average age 38.5 years) and average height 14.3 m. Average d.b.h. in Data File 5 was 28.9 cm (average age 66.8 years and average height 22.5 m). This represents a d.b.h. change of 10.9 cm (increase by about 60%) and a tree height change of 8.2 m (increase by 57%) in the period of 30 years. Regarding the absence of resolution of the respective GFT, the data can be considered as only informative.

More detailed mensurational measurements of Serbian spruce were made on GFT 2D, 2S, 3H, 3J, 3W, 4A and 4K. The average values of d.b.h. and tree height for these tree groups growing in the individual GFT in the conditions of the Training Forest Enterprise can be presented with an error of standard deviation of 15%. Growth characteristics in the data files are presented by average age at measure-

Table 3. Average mensurational data of some GFT

Group of forest types		Number (pcs)	Age (years)	Diameter (cm)	Standard deviation	Error of standard deviation (%)	Height (m)	Standard deviation	Error of standard deviation (%)	Stem-volume (m^3)
2D	S1	22	34.0	18.18	2.757	15				
	S2	22	41.0	21.68	3.153	15	15.9	1.766	15	0.31
	S3	22	49.0	24.27	3.387	15	18.6	1.884	20	0.45
	S5	22	66.0	29.27	4.674	15	23.6	2.242	15	0.81
2S	S1	39	34.7	17.97	4.616	15				
	S2	34	43.3	22.15	5.786	15	15.0	2.647	15	0.33
	S3	25	49.0	24.80	5.477	15	16.8	2.541	20	0.44
	S5	15	66.9	33.80	7.055	20	21.9	2.441	20	0.98
3H	S1	281	34.8	16.39	4.613	5				
	S2	276	41.4	19.46	5.150	5	15.7	2.169	10	0.26
	S3	252	49.0	22.47	5.801	5	16.7	5.096	10	0.38
	S4	139	60.0	29.26	5.852	10	21.5	2.413	10	0.73
	S5	200	65.7	29.79	7.207	5	22.2	2.682	10	0.80
3J	S2	47	42.0	15.81	3.553	10	15.6	3.739	15	0.17
	S5	40	72.0	23.59	6.093	10	22.3	7.991	10	0.53
3W	S1	78	34.7	16.62	4.980	10				
	S2	66	41.6	17.88	5.973	10	16.1	2.243	10	0.24
	S3	43	49.0	19.77	6.981	10	18.2	1.794	15	0.33
	S5	20	67.0	26.74	6.486	15	23.8	1.997	15	0.71
4A	S1	155	36.0	16.05	4.391	10				
	S2	131	41.0	17.21	4.850	10	16.2	2.937	10	0.21
	S3	92	49.0	18.96	5.162	10	18.3	3.746	10	0.29
	S5	70	67.0	25.83	6.917	10	22.0	2.809	10	0.63
4K	S1	30	36.0	21.07	5.112	15				
	S2	27	41.1	24.78	4.848	15	17.6	1.291	20	0.46
	S3	25	49.0	27.56	4.327	10	21.0	1.473	15	0.64
	S4	22	59.0	33.05	5.076	15	25.0	1.834	15	1.05
	S5	22	67.0	35.53	5.957	10	27.0	1.367	20	1.34

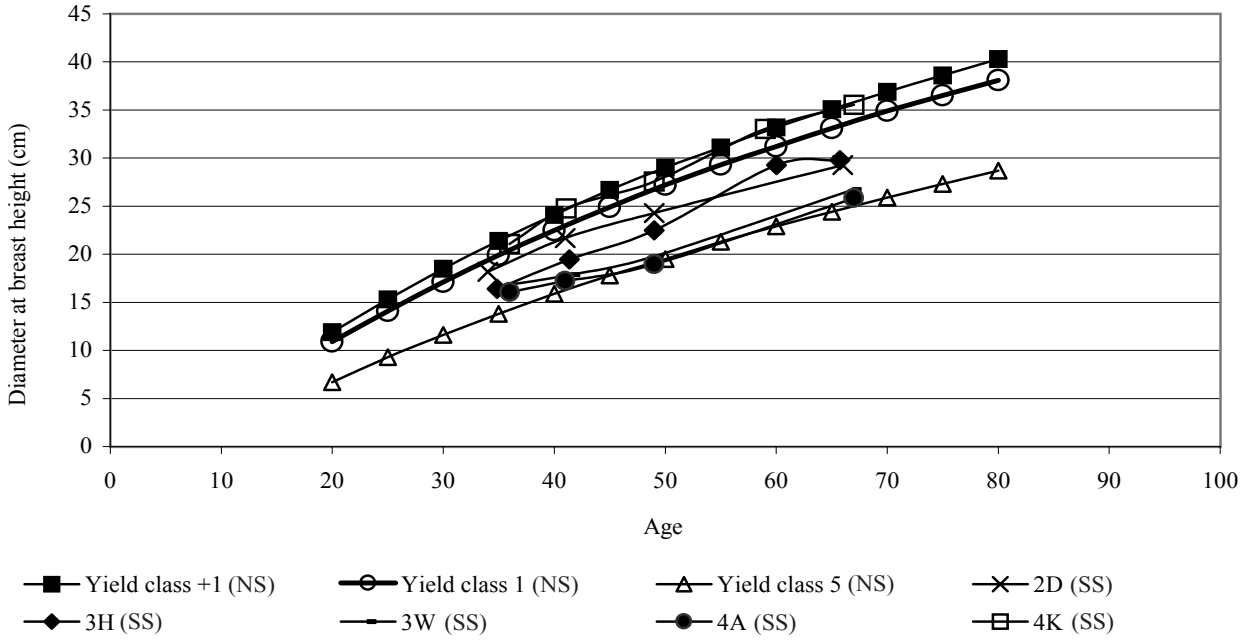

Fig. 1. Comparison of mean stem d.b.h. variations in Norway spruce (NS) (according to tables for the development of 20-year old stand) with the Serbian spruce (SS) growing at the Training Forest Enterprise Křtiny

ment. The individual data files have the standard deviation and its error for the sufficient file size valid for the given data file in the GFT (Table 3).

It was found out from the achieved values, numbers of individuals, most extensive groups on GFT 3H, 4A and GFT 4K (Table 3) that the largest increment is that of Serbian spruce growing on GFT 4K. The group on GFT 3H reached d.b.h. = 16.4 cm at the age of 35 years; the group on GFT 4A reached d.b.h. = 16.05 cm and that on 4K d.b.h. = 21.1 cm. After about 30 years, the average d.b.h. of trees was 29.8 cm (increase by 82%) – height 22.2 m – av. Derbholz volume over bark 0.80 m^3 on GFT

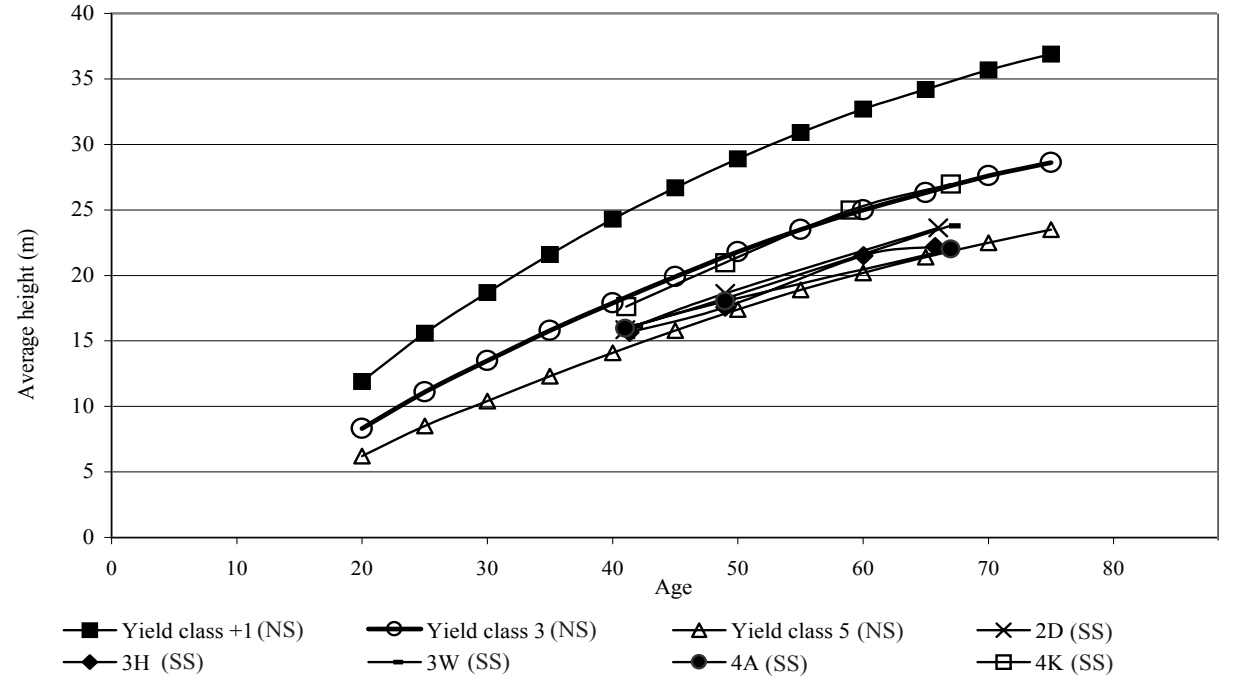

Fig. 2. Comparison of mean stem height variations in Norway spruce (NS) (according to growth tables for the development of 20-year old stand) with the Serbian spruce (SS) growing at the Training Forest Enterprise Křtiny

3H; 25.83 cm (increase by 61%) – height 22.0 m – av. Derbholz volume over bark 0.63 m^3 on GFT 4A; and 35.5 cm (increase by 68%) – height 27 m – av. Derbholz volume over bark 1.34 m^3. The markedly greater size and av. stem volume of Serbian spruce growing on GFT 4K probably result from the sufficient rainfall, abundant surface moisture and acidic soil. Similar site characteristics for above-average growth of Serbian spruce are mentioned by KLIKA (1953).

A comparison of variations in average growth values of Serbian spruce on the selected GFT with the development of mean stem of 20-year old Norway spruce stand according to Appendix 3 of Decree No. 84/1996 of the Ministry of Agriculture to Forest Act No. 289/1995 provided the following data:

The Serbian spruce plantations on GFT 4K reach over time the average d.b.h. values comparable with the tabular Norway spruce of yield class +1 (AVB36) (Fig. 1). Their height values are similar to those of Norway spruce of yield class 3 (AVB30) (Fig. 2). This can result from a more opened growth of crowns with spruces usually having enough space.

In terms of d.b.h., Serbian spruce growing on GFT 2D and 3H reaches up only to the Norway spruce of yield class 2–3 (AVB 32–30). In terms of diameter increment, Serbian spruce on GFT 4A reaches up only to the Norway spruce of yield class 5 (AVB 26). As to tree height, all three plantations by GFT reach up only to the Norway spruce of yield class 5 (AVB 26). The fifth measurement made on GFT 3H is somewhat deviated which results from the composition of data and from the fact that it was impossible to assess all localities. The data have been included in the graph for completeness.

The largest stem diameter in a living specimen of Serbian spruce at TFE Křtiny (Table 4) is that of Tree 15 in Locality 65; the tree achieved d.b.h. = 49.3 cm and height of 26 m at the age of 66 years. The greatest height is that of Tree 8 in Locality 32 with d.b.h. = 47 cm and height 30 m, which has at the same time the greatest tabular Derbholz volume over bark = 2.26 m^3.

GFT 3H was chosen to be an exhibit for the comparison of d.b.h. distribution of Serbian spruce in the diameter intervals of individual sets of measurements due to its largest range. It was found out that Class 18 was most frequently represented as at the year 1970 with the curve shape being normal, pointedness –0.22 and obliqueness 0.24. The curve gradually shifts to higher diameter intervals and becomes flatter its pointedness and obliqueness being –0.41 and 0.19 in 1983, –0.31 and 0.22 in 2001, respectively. In 1983, two peaks appear in the frequency

Table 4. Mensurational values of largest Serbian spruce individuals

Locality	32	41	43	65	32	32	28	43
Number in locality	2	8	1	15	5	19	5	2
Forest type	4H1	3H1	3H1	2S2	4K5	4K5	4A5	3H1
Altitude (m)	500	470	450	350	500	500	480	450
Age at 1st measurement	36	36	35	35	36	36	36	35
d.b.h. (cm)	24	27	28	24	30	22	27	28
Age at 2nd measurement	41	44	42	44	41	41	41	42
d.b.h. (cm)	31	34	33	33	32	26	30	32
Height (m)	18.5	20.0	18.0	17.0	18.0	18.0	17.0	18.0
Stem volume (m^3)	0.69	0.86	0.73	0.69	0.69	0.47	0.58	0.69
Age at 3rd measurement	49	49	49	49	49	49	49	49
d.b.h. (cm)	33	38	37	38	34	28	32	34
Height (m)	22.0	20.0	22.0	21.5	22.0	21.5	20.5	22.5
Stem volume (m^3)	0.89	1.04	1.10	1.15	0.94	0.66	0.81	0.99
Age at 4th measurement	59	60			59	59		
d.b.h. (cm)	43	44			40	38		
Height (m)	26.5	26.5			26.5	25		
Stem volume (m^3)	1.75	1.82			1.54	1.31		
Age at 5th measurement	67	65	67	66	67	67	67	67
d.b.h. (cm)	47	47	47	49	43	43	42	42
Height (m)	29.0	30	27.5	26.0	27.0	27.5	27.0	27
Stem volume (m^3)	2.19	2.26	2.12	2.11	1.75	1.82	1.68	1.68

An absolutely most sizeable Serbian spruce at the TFE Křtiny is Tree 5 from GFT 3H in the Křtiny Arboretum with a presumed age of 101 years. Its d.b.h. is 53 cm, height 27 m and Derbholz volume over bark 2.49 m^3. Regarding the fact that data on the growth of this tree are not available from previous years, we can compare only the present data. The tree grows unshaded in the open area within the reach of groundwater from an adjacent pond and from the height of 16 m up has two stems.

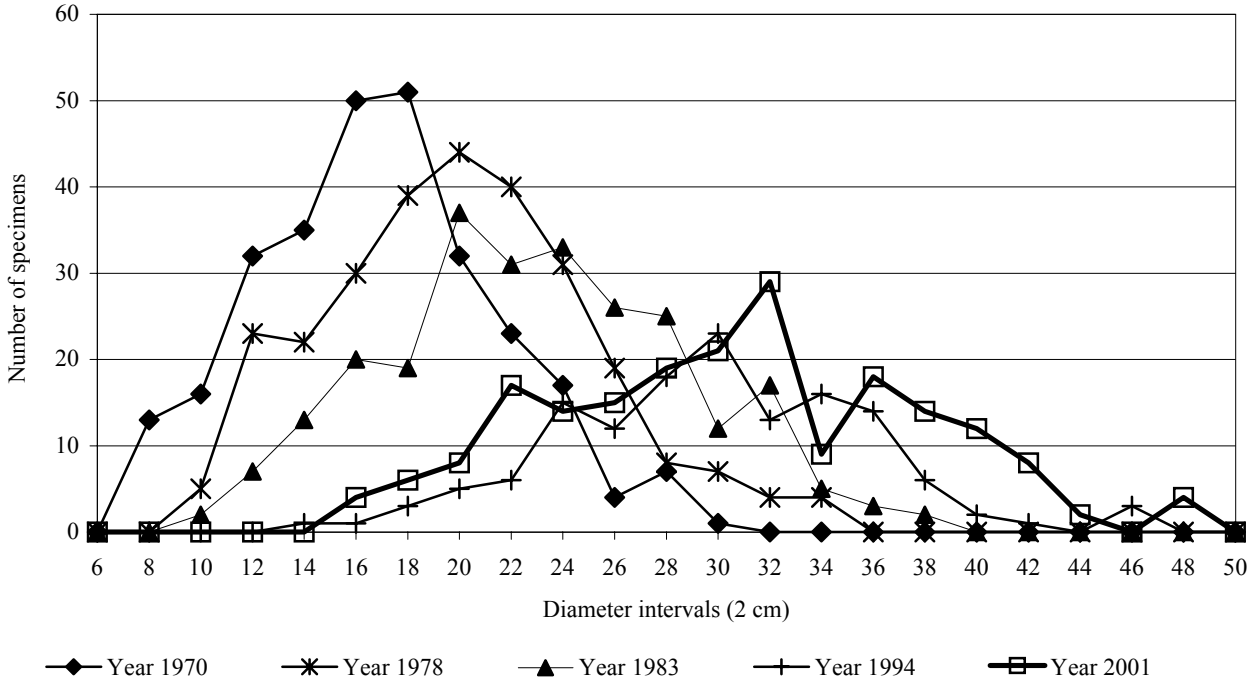

Fig. 3. Development of representation of individuals in diameter intervals in dependence on age as at 2001, respective inventory data files from GFT 3H, individuals of Serbian spruce at the Training Forest Enterprise Křtiny

stratification of individual intervals (diameter intervals 20 and 24). Since a half of individuals grow in Locality 67, the reason must be sought there. According to oral testimonies of those who remember there were several trees of Serbian spruce felled here in 1980 due to their infestation with bark beetle; hence the two mentioned peaks, which are still obvious at the last measurement in 2001 (Fig. 3).

Serbian spruce growing in unfenced and freely accessible plantations is damaged by wildlife at an approximately similar level as Norway spruce. Stems abraded by wild boar, which has a natural range here, can be found only in open localities with a group of Serbian spruces. Thanks to its low-branching crown, Serbian spruce should not exhibit damage by red deer.

It is only the largest groups of Serbian spruce plantations that are further assessed for the occurrence of more stems and mortality. Site conditions are not given emphasis as great as growth conditions with regard to a great influence of other factors such as game or human interventions. It is assumed that in the course of 70 years from planting the groups passed through not only different views of forest property administration but – unlike standard stands – also through other external effects.

The change in the number of Serbian spruce specimens can be characterized as not too pronounced and rather corresponding to the natural mortality of trees (Table 5). In Locality 67 on GFT 3H there are 121 individuals today remaining from the original 177 individuals in 1934, which represents a loss of 32%. If we investigated this locality for mortality by the respective measurements, we would find out that the reduction in the number of trees is in relative expression constant – about 10% in 10 years. With respect to the fact that

Table 5. Changes in the number of individuals and in the number of specimens with multiple stems

Locality	GFT	Number (pcs) (1967–1970) total	of these with 2–3 stems	(%)	Number (pcs) (1998–2001) total	reduction by	(%)
28	4A	179	0	0	70	109	61
32	4K	32	8	25	23	9	28
48	3J	50	0	0	42	8	16
59	3H	94	15	16	63	31	33
67	3H	177	32	18	121	56	32
Total		532	55	10	319	213	40

Table 6. Comparison of seed characteristics found in Serbian spruce

	Cone length (mm)	Cone width (mm)	Weight of cone with seeds (g)	Weight of cone without seeds (g)	Number of seeds (pcs)	Number of undevel. (pcs)	Weight of winged seeds in the cone (g)	Weight of 1,000 winged seeds (g)	Absolute weight (g)
Min	20	10	1.24					1.5	1.1
Max	60	20	9.21					4.95	4.1
Average	55		4.03				0.095		
Author	VIDAKOVIĆ	VIDAKOVIĆ	KRSTIĆ				KRSTIĆ	KRSTIĆ	KRSTIĆ
Min	20	13	3.70					2.65	
Max	68	30	5.26					3.61	
Average								3.24	
Author	JOVANOVIĆ	JOVANOVIĆ	JOVANOVIĆ					SCHOPMEYER	
Min	46.20			4.11	10.00	1.00	0.02	0.61	
Max	63.10			9.23	55.00	10.00	0.24	4.94	
Average	54.21			7.05	31.41	5.86	0.12	3.95	
Coll. year	1999			1999	1999	1999	1999	1999	
Min	46.50	14.90	3.76						
Max	63.60	18.70	8.93						
Average	55.58	17.01	6.24						
Coll. year	2001	2001	2001						

the whole arboretum is fenced and thus protected from game damage, an absolute majority of cases were due to abiotic factors or competition, an exception being the loss of 17 trees between the years 1994 and 1999, which resulted from an overpopulation of spruce bark beetle (*Ips typographus* [L.]) in 1997. Other localities show a similar change in the tree numbers with an exception being Locality 28, which is partly situated in an upland on a limestone outcrop. Here, a regular decrease of 40 trees (ca. 20%) was recorded in the 10-year intervals of the measurements. The reason is seen in frequently occurring periods of drought, which is borne witness to total absence of the higher tree layer in the locality despite a considerable openness of the stand.

Similarly like in the occurrence of stem damage, the frequency of specimens with more stems can be explained by zero application of silvicultural measures (Table 5). It was found out by summarizing the data from Locality 67 of Řícmanice arboretum on GFT 3H where the plantations are intentionally grown with more open canopies and in rather park – like manner that in the year 1969 there were 32 specimens with 2 to 3 stems of the total 177 trees (ca. 18%). In contrast, Locality 28 on GFT 4A whichis comparable in size and was planted and tended as a relatively normal forest stand did not exhibit from a total of 179 trees a single specimen with 2 or 3 stems in 1970.

Stem growth defects other than multiple stem occurring in Serbian spruce are also represented by twisted stem whose incidence is however rather exceptional. Unlike our spruce, Serbian spruce never develops large-diameter lower branches which would devaluate the wood mass in spite of the fact that its branching is persistently reaching down to the ground. The branches are in contrast rather thin until old age. This is why Serbian spruce must be partly grown in open canopies. In localities in which it was grown in denser canopies and particularly on the nutrient-rich sites it got shaded by faster-growing autochthonous species and dwarfed.

Our observations indicate that crop occurs every year in Serbian spruce and seed years arrive at intervals of about 3–4 years. The last above-average crop arrived in 2001. Measurements made in this year also included an ocular estimate of fertility of individual trees. From a total of 183 measured trees 132 (72%) were fully fructifying, 23 (13%) partly fructifying (numbers of current year cones not exceeding 10–50 pcs) and 28 (15%) not fructifying at all (less than 10 cones). Non-fructifying trees were usually subdominant and exhibiting poor increment.

Like our autochthonous species, Serbian spruce brings fruits in the seed years. Mass natural regeneration occurs in several localities (locality 28 on GFT 4K in particular) with favourable natural conditions.

Table 6 presents data on sizes and weights of Serbian spruce seeds and cones from different authors and includes also the author's own measurements obtained from Řícmanice arboretum and complemented with data file standard deviations. The measured sizes do not differ from the average values of other authors with an exception of cones that reach slightly larger lengths.

CONCLUSION

Serbian spruce plantations at the Training Forest Enterprise Křtiny represent one of the most extensive areas with the species in the open nature existing in the territory of the Czech Republic. Serbian spruce grows in this region in the most varied natural conditions similar to those existing in a major part of the country's territory. It was demonstrated by assessing approximately 70-year old Serbian spruce plantations at the TFE Křtiny that the spruce is capable of reaching nearly the same dimensions as our domestic Norway spruce provided that some necessary biological and silvicultural conditions are fulfilled.

It was found out that Serbian spruce growing on GFT 4K does as good in terms of its growth as the tabular Norway spruce of yield class +1. In seasoning localities on GFT 4A it can surmount with its growth and replace a majority of domestic species growing there. Unlike Norway spruce it does not like a full shade, especially by deciduous tree species on nutrient-rich sites; in such conditions it shows a poor increment retarding first only in diameter growth and later also in height growth. It requires a somewhat open canopy.

For all these reasons, the use of Serbian spruce will always remain at the level of aesthetics. The upright habit and deeply branching crown predetermine the species for towns and landscapes with high recreational loads. If it is planted onto decorative glades in homogeneous groups, it will always represent a beautifying element. Other features of the species to be mentioned are its hardiness to early and late frosts and its resistance to dust and urban environment, which are verified from many plantations perhaps in all larger towns of not only the Czech Republic.

With regard to a somewhat more abundant incidence of wood mass defects in experimental plantations (frequent resinization of wounds, relatively frequent incidence of twin and triple stems), normal commercial use of the species can hardly be expected. However, when assessing the plantations, we must not forget the non-application of silvicultural measures.

Serbian spruce fructifies in seed years similarly as our domestic tree species and develops the spontaneous natural regeneration on favourable sites. Younger stands at the TFE Křtiny have been planted from seeds obtained from the fructifying specimens.

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Zhodnocení růstu *Picea omorika* [Panč.] Purkyně na území ŠLP Masarykův les Křtiny

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ABSTRAKT: Výsadby smrku omoriky (*Picea omorika* [Panč.] Purkyně) dosahují na ŠLP Masarykův les Křtiny věku přes 70 let. Nacházejí se na rozdílných stanovištích na ŠLP Křtiny. Ten se rozkládá severně od Brna mezi obcemi Blansko, Jedovnice a Brno v České republice. V článku jsou hodnoceny základní dendrometrické hodnoty (výčetní tloušťka $d_{1,3}$, výška h, objem hroubí m^3) a také plodnost, úmrtnost i celkový zdravotní stav. Z původních 750 exemplářů smrku omoriky jich nyní bylo zaevidováno 425 na 25 lokalitách a 12 SLT. Při porovnání dendrometrických údajů smrku omoriky s růstovými tabulkami bylo zjištěno, že omorika vyrovnává na SLT 4K tabulkové střední hodnoty smrku ztepilého (*Picea abies* [L.] Karst.) bonity +1.

Klíčová slova: zhodnocení růstu; lokality; introdukované dřeviny; smrk omorika; soubor lesních typů

Výsadby smrku omoriky (*Picea omorika* [Panč.] Purkyně) v oblasti Školního lesního podniku Masarykův les Křtiny (ŠLP) jsou jako celek jednou z nejrozsáhlejších výsadeb této dřeviny ve volné přírodě na území České republiky. Smrk omorika zde roste v nejrozličnějších přírodních podmínkách podobných většině území ČR. V současné době je na území ŠLP rozmístěno asi 25 lokalit s výsadbami smrku omoriky; ty se nacházejí v nadmořských výškách od 290 m do 575 m.

Většina hodnocených výsadeb vzrostlých exemplářů smrku omoriky v porostech, v arboretech a na okrasných paloucích dosahuje v dnešní době 70 let. Pocházejí ze semene smrku omoriky z bývalé Jugoslávie. Nejstarší sazenice byly v letech 1934 a 1935 vysazovány na estetické palouky. Mladší sazenice byly v následujících letech vysazovány do různých porostů na celém ŠLP.

Hodnocené údaje byly získávány při venkovních měřeních v letech 1999–2001. U výsadeb smrku omoriky byly měřeny výčetní tloušťky $d_{1,3}$ (cm) a výšky (m) jednotlivých stromů pomocí standardních dendrometrických postupů. Současně byl sledován zdravotní stav zkoumané dřeviny (abiotická poškození a napadení lesnicky významnými škůdci, popřípadě poškození zvěří), množství kmenů, plodnost v době měření, výskyt přirozeného zmlazení. Pro vyhodnocení získaných dat byla všechna měření roztříděna do pěti souborů dat s devítiletým intervalem počínaje v 29 letech (tab. 1). Toto roztřídění umožňuje nepravidelná měření seskupit do přibližně stejně starých (a stejně velkých skupin) stromů (tab. 2).

Z celkem 750 záznamů stromů je 653 jedinců evidováno k roku 1970, kdy končila první souhrnná evidence. Po skončení současné celkové inventarizace bylo evidováno 425 žijících stromů; z nich bylo do hodnocení zahrnuto 408 stromů.

Podrobněji jsou zhodnocena dendrometrická měření smrku omoriky rostoucího na SLT 2D, 2S, 3H, 3J, 3W, 4A a 4K. U jednotlivých souborů dat (tab. 3) je uveden počet hodnocených jedinců, jejich průměrný věk, průměrná tloušťka a výška se směrodatnou odchylkou a její chybou pro dostatečnost velikosti souboru dat na SLT a hmotnatost.

Z dosažených hodnot množství jedinců nejrozsáhlejších skupin stromů na SLT 3H, 4A a SLT 4K bylo zjištěno, že nejrychleji přirůstající je smrk omorika rostoucí na SLT 4K. Zde svým růstem vyrovná tabulkový smrk ztepilý (*Picea abies* [L.] Karst.) bonity +1. Na vysýchavých lokalitách na SLT 4A dokáže smrk omorika růstem předčit a nahradit většinu domácích zde rostoucích dřevin. Skupina stromů na SLT 3H dosáhla ve věku 35 let výčetní tloušťky $d_{1,3}$ 16,4 cm; na 4A 16,05 cm a na 4K 21,1 cm. Po přibližně 30 letech je průměrná tloušťka $d_{1,3}$ stromů na 3H 29,8 cm (nárůst o 82 %) s výškou 22,2 m a s průměrným objemem hroubí s.k. 0,80 m^3; na SLT 4A 25,83 cm (nárůst o 61 %) s výškou 22,0 m a objemem hroubí s.k. 0,63 m^3; SLT 4K 35,5 cm (nárůst o 68 %) s výškou 27 m a objemem hroubí s.k. 1,34 m^3. Smrk omorika na rozdíl od smrku ztepilého nesnáší úplné zastínění zejména listnatými dřevinami na bohatších stanovištích. V takových podmínkách nepřirůstá a zaostává zpočátku pouze v tloušťkovém, později i ve výškovém růstu. Celkově vyžaduje růst ve volnějším zápoji než smrk ztepilý.

Nejsilnější nalezený žijící exemplář smrku omoriky na ŠLP (tab. 4) je strom č.15 na lokalitě 65, který ve věku 66 let dosáhl výčetní tloušťky $d_{1,3}$ 49,3 cm a výšky 26 m. Nejvyšší výšky dosáhl strom č. 8; lokalita 32, s výčetní tloušťkou $d_{1,3}$ 47 cm a výškou 30 m; současně má i nejvyšší tabulkový objem hroubí s.k. – 2,26 m^3.

U neoplocených volně přístupných výsadeb je smrk omorika poškozován zvěří srovnatelně jako smrk ztepilý. Pouze na otevřených lokalitách, kde je skupinka smrků omorik, lze pozorovat odřené kmeny od černé zvěře, která zde má přirozené pobytové místo. Díky své hluboce zavětvené koruně by u něj nemělo docházet k poškozování jelení zvěří.

Smrk omorika plodí podobně jako naše domácí dřeviny v semenných letech, která se opakují přibližně po třech až čtyřech letech. Nadprůměrná úroda byla naposledy v roce 2001. Na příznivých stanovištích tvoří spontánní přirozené zmlazení. Mladší výsadby smrku omoriky na ŠLP jsou již vysazovány z osiva získaného z plodících exemplářů.

Vzhledem k poněkud hojnějšímu výskytu vad dřevní hmoty u sledovaných výsadeb (časté zasmolování ran, relativně častý je také výskyt dvojáků a trojáků) u smrku omoriky nelze předpokládat běžné používání jako hospodářské dřeviny. Při jeho hodnocení však nesmíme zapomínat na to, že u většiny pokusných porostů nebyla uplatňována pěstební opatření.

Přesto – nebo možná právě proto – zůstane využití smrku omoriky v rovině estetické. Jeho vzpřímený habitus a hluboce zavětvená koruna ho předurčují do měst a do krajiny s velkou rekreační zátěží. Pokud se vysazuje na okrasné palouky v homogenních skupinách, tvoří vždy výrazný okrášlovací prvek. Neměla by být opomenuta jeho otužilost proti časným a pozdním mrazům a také odolnost vůči prachu a městskému ovzduší, která je ověřena z mnoha výsadeb snad ve všech větších městech nejen České republiky.

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