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Production potential and ecological stability of mixed forest stands in uplands – V. A mixed spruce/beech stand on a nutrient-rich site of the Křtiny Training Forest Enterprise

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ABSTRACT: The study is already the 5th account on the production potential and stability of mixed forest stands in uplands. A spruce/beech stand established in the mid-30s of the 20th century is assessed. The stand is situated at an altitude of 470 m and since 1960, it is left to its spontaneous development. At that time, the stand was characterized as a silviculturally neglected dense spruce young growth to a small pole-stage stand with an admixture of beech (spruce 71%, beech 13%). In the course of 41 years, spruce proportion in the stand without intentional thinning measures decreased from 71 to 56% and, vice versa, beech proportion increased from 13 to 31%. Present dominant and co-dominant position of spruce in the stand, its health condition and development in recent years indicate that the ecosystem under evaluation is stabilized fulfilling all functions on the given site at an age of 65 years. The stand is permanently fully stocked and its initial standing volume of 109 m^3/ha at an age of 24 years in 1960 increased to 560 m^3/ha at an age of 65 years in 2001.

Keywords: mixed stands; spruce; beech; natural development; production; increment; stability

OUTLINE OF PROBLEMS

The 5th study of an extensive project *Production Potential and Ecological Stability of Mixed Forest Stands in Uplands* evaluates a mixed spruce/beech stand on a nutrient-rich site of the 3rd and 4th forest vegetation zones. It refers to a relatively "simple" but from the production and ecological point of view extraordinarily important basic mixture of main tree species of not only montane and sub-montane but also upland regions.

Findings on the production potential of spruce/beech stands of the last century were analysed by KANTOR (1981) at the beginning of the 80s. This compilatory paper summarizes results of more than 50 Czech and foreign studies evaluating interrelations of spruce and beech in mixed stands not only from the aspect of maximum production but also from the viewpoint of safety and stability of production.

From the point of view of the total amount of production under upland conditions the highest production was reached by unmixed spruce stands or by spruce stands with an admixture of 10–20% of beech. In addition to species composition, the total amount of production of spruce/beech stands is affected by the form of mixture, method of the stand establishment, their tending etc.

Results of the majority of studies have shown that spruce stands usually increase acidity of forest soils. On the contrary, deterioration of other soil characteristics due to unmixed spruce has not tbeen, however, explicitly proved. Possible changes in pedological processes brought about by spruce need not to be automatically accompanied by a decrease in forest soil fertility (KANTOR 1981).

Studies on the importance and position of mixed forest stands show a long-time tradition in all countries with advanced forestry (in our country e.g. CHADT 1922; KONŠEL 1924; ŠKODA 1925). From the viewpoint of quality and quantity, these issues obtained a new character in recent 25 years particularly in connection with uncertainties of the development of climate in next decades.

For example, databases of the Department of Forest Establishment and Silviculture, Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry, Brno include more than 500 citations of scientific and special studies coming from 1980 to 2003 assessing and evaluating mixed spruce/beech stands from various aspects. Optimum stand establishment has been dealt

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Table 1. Basic mensurational data of the control plot of stand 23E6 in 1960–2001

Species	Number of trees per hectare (*N*)	Mean tree			Stand basal area (b.a.) (m^2/ha)	Growing stock (m^3/ha)	Stand density	Species composition (%)
		h (m)	d.b.h. (cm)	v (m^3)				
1960 – age 24								
Norway spruce	2,675	8.5	8.6	0.032	18.2734	86.2	0.76	71.2
Beech	1,090	6.8	4.6	0.007	2.4003	8.1	0.14	13.3
Pine	75	9.6	14.3	0.086	1.3476	6.5	0.05	4.9
Larch	150	9.0	9.1	0.033	1.1409	4.9	0.05	4.9
Oak	290	6.4	4.9	0.007	0.7230	2.2	0.04	3.7
Birch	10	11.4	14.4	0.095	0.1795	1.0	0.01	0.8
Hornbeam	340	5.5	2.2	0.002	0.1658	0.6	0.01	1.2
Total	4,630				24.2305	109.4	1.06	100.0
1967 – age 31								
Norway spruce	2,100	11.9	11.0	0.071	22.5364	149.7	0.80	70.0
Beech	870	9.7	6.2	0.019	3.3896	16.7	0.17	14.9
Pine	70	13.4	16.5	0.152	1.6485	10.7	0.05	4.6
Larch	125	12.9	11.5	0.077	1.4315	9.6	0.06	4.8
Oak	185	9.9	7.4	0.022	0.9430	4.2	0.05	4.1
Birch	10	15.3	18.2	0.185	0.2750	1.9	0.01	0.9
Hornbeam	130	8.2	3.3	0.005	0.1254	0.7	0.01	0.7
Total	3,490				30.3495	193.3	1.15	100.0
1971 – age 35								
Norway spruce	1,510	15.8	13.6	0.140	24.1013	211.9	0.74	67.9
Beech	660	12.5	8.0	0.039	4.1199	25.5	0.19	17.2
Pine	60	16.4	18.7	0.218	1.7190	13.1	0.05	4.5
Larch	100	16.3	13.6	0.131	1.5529	13.1	0.05	4.9
Oak	110	14.1	10.4	0.061	1.0127	6.7	0.05	4.2
Birch	10	20.0	21.5	0.320	0.3790	3.2	0.01	1.2
Hornbeam	10	11.7	4.9	0.010	0.0186	0.1	0.00	0.1
Total	2,460				32.9033	273.6	1.09	100.0
1976 – age 40								
Norway spruce	1,320	17.6	15.0	0.188	25.4191	248.5	0.73	65.6
Beech	590	14.1	9.1	0.059	4.8150	34.8	0.21	18.6
Pine	60	17.8	19.5	0.261	1.8954	15.7	0.05	4.8
Larch	100	17.7	14.3	0.162	1.7436	16.2	0.06	5.2
Oak	105	16.1	11.6	0.089	1.2008	9.4	0.05	4.5
Birch	10	22.5	22.8	0.395	0.4215	4.0	0.01	1.2
Total	2,185				35.4954	328.4	1.11	100.0
1996 – age 60								
Norway spruce	630	24.1	22.6	0.547	26.9305	344.5	0.63	57.7
Beech	315	19.6	16.4	0.299	8.3424	94.3	0.31	27.8
Pine	25	24.3	25.9	0.590	1.3591	14.8	0.03	2.9
Larch	60	24.4	21.4	0.498	2.2963	29.9	0.06	5.6
Oak	35	23.3	21.3	0.414	1.2477	14.5	0.04	4.0
Birch	10	27.0	30.1	0.780	0.7126	7.8	0.02	1.8
Total	1,075				40.8886	505.7	1.10	100.0
2001 – age 65								
Norway spruce	525	25.9	25.1	0.705	27.6673	370.0	0.61	55.5
Beech	275	21.5	19.2	0.435	10.0778	119.6	0.35	31.3
Pine	15	26.6	27.4	0.720	0.9120	10.8	0.02	1.9
Larch	50	27.2	23.9	0.687	2.3591	34.3	0.06	5.3
Oak	35	24.5	22.3	0.483	1.3786	16.9	0.05	4.1
Birch	10	28.0	31.1	0.865	0.7616	8.7	0.02	1.9
Total	910				43.1565	560.3	1.11	100.0

Table 2a. The development of Norway spruce frequency in height classes (m) and **mortality** in the control plot of stand 23E6 (0.20 ha) in 1960–2001

Height class (m)	1960	**1960 to 1967**	1967	**1967 to 1971**	1971	**1971 to 1976**	1976	**1976 to 1996**	1996	**1996 to 2001**	2001
2	14	**12**	2	**2**							
3	19	**15**	3	**2**	1	**1**					
4	20	**14**	6	**5**	1		1	**1**			
5	27	**22**	2	**2**							
6	47	**28**	6	**3**							
7	49	**14**	19	**17**	3	**2**					
8	63	**8**	25	**24**			1	**1**			
9	89	**2**	23	**18**	1		1	**1**			
10	92		40	**23**	8	**5**	1	**1**			
11	70		37	**8**	9	**4**	6	**6**			
12	25		56	**9**	20	**12**	4	**4**			
13	9		61	**4**	22	**4**	10	**10**			
14	10		61	**1**	41	**8**	21	**20**			
15	1		52		29		18	**17**	1		
16			17		32	**2**	31	**26**	1	**1**	
17			7		43		33	**23**	3	**2**	1
18			3		37		36	**18**	5	**2**	
19					33		33	**6**	3	**2**	3
20					11		32	**1**	9	**2**	4
21					7		20	**3**	3	**1**	1
22					1		8		8	**2**	4
23					2		4		16	**4**	7
24					1		2	**1**	19	**3**	4
25							1		13	**1**	21
26									18	**1**	18
27									9		11
28							1		11		16
29									5		8
30									1		5
31											1
32									1		
33											1
Total	535	**115**	420	**118**	302	**38**	264	**139**	126	**21**	105
Per ha	2,675	**575**	2,100	**590**	1,510	**190**	1,320	**695**	630	**105**	525
Mean height	8.5	**5.1**	11.9	**8.7**	15.8	**11.9**	17.6	**15.6**	24.1	**21.1**	25.9

with in the mixture (HÄBERLE 1997; WEINFURTER 1988; TRAUBOTH, KRAUSS 1996; ŠINDELÁŘ 1997; KOŠULIČ 1992) as well as principles of tending in thickets and pole-stage stands (AHBE et al. 1996; SANIGA 1990, 1994; KRISCH, MÜLLER 1998; ŠTEFANČÍK I., ŠTEFANČÍK L. 1998; OTTO 1986). A number of comparative papers is also available comparing the production potential of spruce/beech stands under various proportion of both species (ZIMMERMANN 1988; SEIBT 1982; NÜSSLEIN 1993; RIEDER 1997; ROTHE, KREUTZER 1998; METTIN 1986; KENK 2002; HEINZE et al. 2001; KORPEĽ 1981). Attention was also paid to the stability and safety of production of the mixture (PODRÁZSKÝ 1996; DIMITRI 1987; BRAUN 1991) and to simulation models of their development (HILLEBRANDT 1997; PRETZSCH 1992, 2000; PRETZSCH, KAHN 1996; HASENAUER et al. 1995).

Finally, it is possible to mention that the position, development, production and stability of spruce and beech in a

mixture with other conifers were analysed and published in a journal Lesnictví-Forestry in the first communication on the project *Production Potential and Ecological Stability of Mixed Forest Stands in Uplands* (KANTOR, PAŘÍK 1998). Within the project, Norway spruce was also evaluated in a mixed stand with Scots pine (4th communication – JELÍNEK, KANTOR 2001).

CHARACTERISTICS OF AN EXPERIMENTAL STAND

Stand 23E6 was established after felling autochthonous beech/fir stands in the mid-30s of the 20th century. Artificial regeneration, largely planting of spruce was naturally completed by partial single tree, clump to group regeneration of other species particularly of beech in the period of the origin of a new stand.

For a period of the first twenty years, the stand was left to its more or less spontaneous development and particularly dead trees were removed only. In 1960, the fact made possible to establish experimental thinning plots in a mixed spruce/beech stand under standard arrangement according to methodical procedures of the Department of Silviculture, Faculty of Forestry and Wood Technology, University of Agriculture and Forestry in Brno.

The stand is situated on a gentle E to SE slope at an altitude of 470 m. Its total area is 7.98 ha. On a bedrock of the Brno effusive rock (biotic granodiorite), soils have been developed of a Cambisol type, mesotrophic subtype. From the viewpoint of typology, the stand is ranked among forest type 3B2.

In the period 1960 to 1976, in research plots of an area of 0.20 ha (series of five partial plots 20 × 20 m) low thinning and crown thinning measures were compared with control plots left to their spontaneous development where dead trees were removed only. The paper presented summarizes and evaluates the natural development of Stand 23E6 in a control plot (no intentional measures) only where the study continues even after 1976 so that at present, results are available of a 41-year time series from 1960 to 2001.

In the time of establishing experimental plots in 1960, the stand was 24 years old being silviculturally neglected and markedly differentiated from the viewpoint of diameter and height.

As for species composition, spruce with admixed beech and other interspersed species (pine, larch, oak, hornbeam and birch) dominated.

METHODS OF FIELD MEASUREMENTS AND RESULT PROCESSING

In the presented paper, similarly as in previous studies I–IV, a control plot was evaluated only. The plot of a total area of 0.20 ha (5 plots 20 × 20 m each) was left to its spontaneous development (no intentional felling measures) for the whole period of examination (41 years).

Methods of the assessment of growth and development of particular experimental stands is unified within the whole research project being published in Lesnictví-Forestry or Journal of Forest Science (KANTOR 1997; KANTOR, PAŘÍK 1998; KNOTT, KANTOR 2000; KANTOR et al. 2001; JELÍNEK, KANTOR 2001).

In regular five-year periods, the following parameters were measured in each of the trees: height, diameter at breast height (d.b.h.), crown height, crown length and crown cover. In the 41-year time series (from 1960 to 2001), in each of the species of a mixture under evaluation the following parameters are separately assessed:
– total frequency and mortality of trees,
– frequency in height and diameter classes,

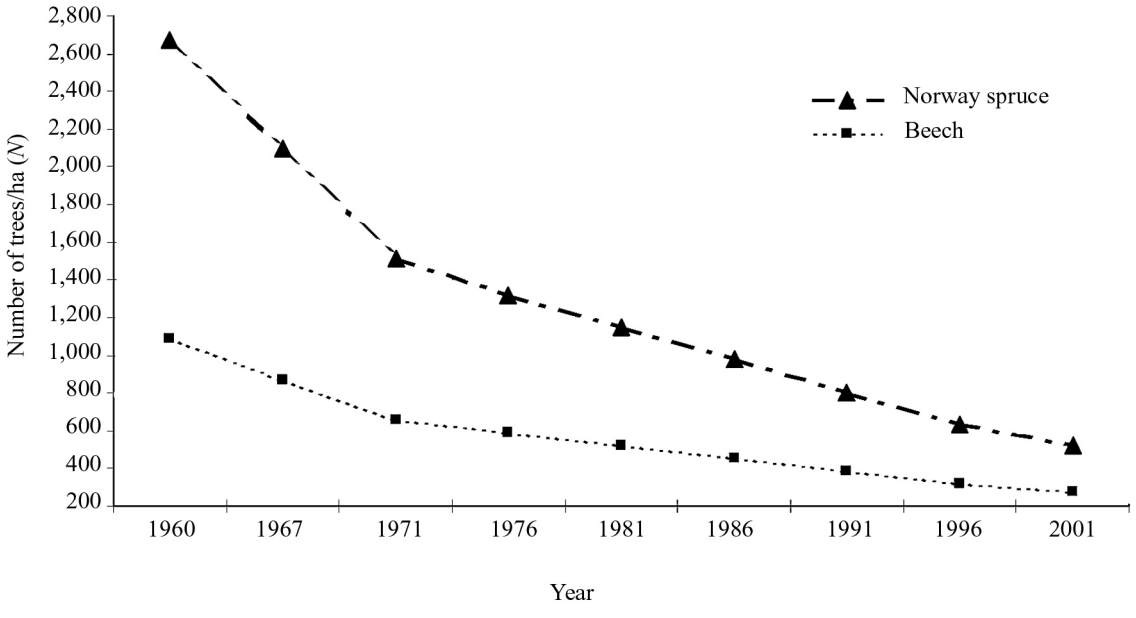

Fig. 1. Development of the number of beech and spruce trees in stand 23E6 (trees/ha)

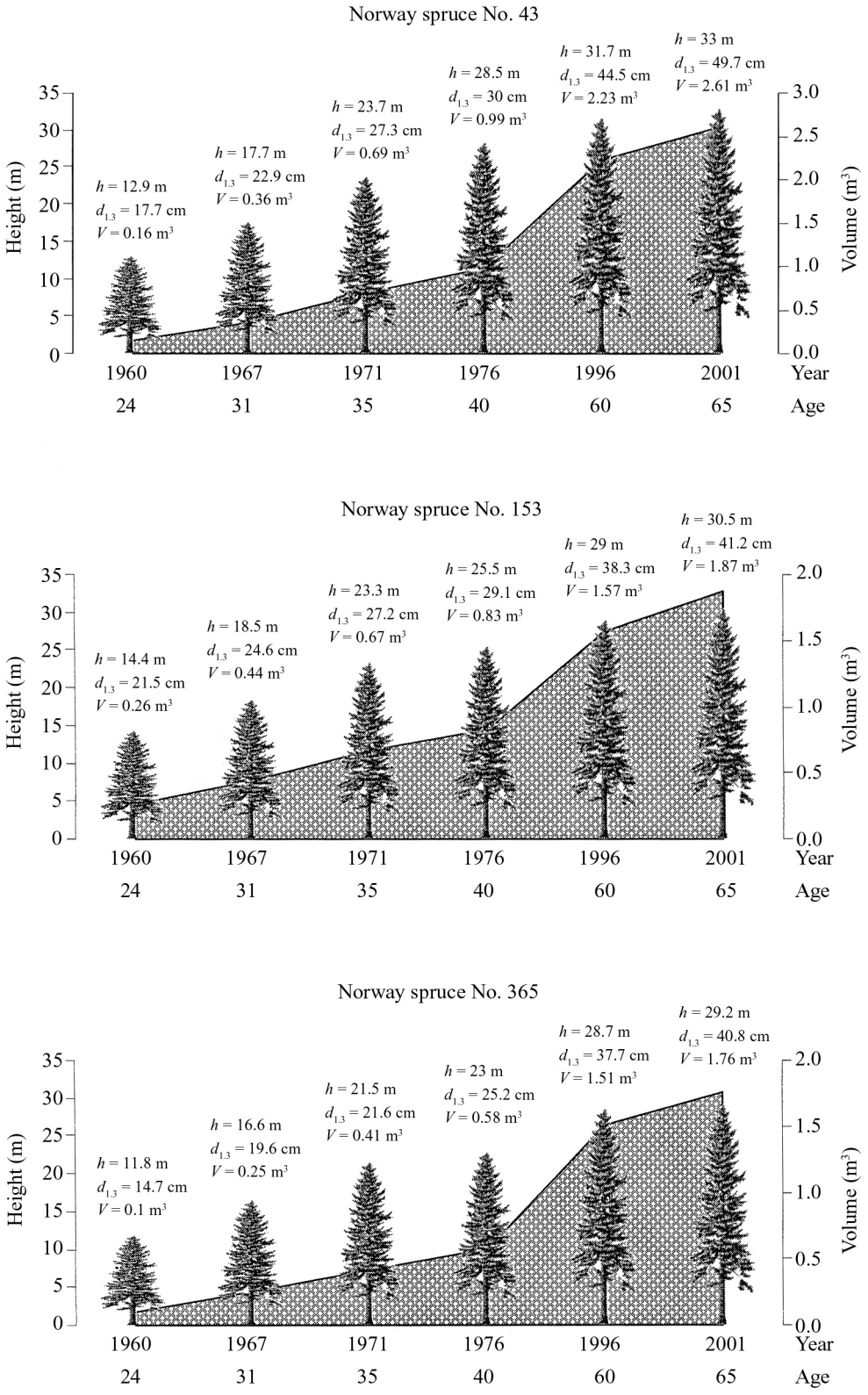

Fig. 2a. Development of spruce trees of the largest volume in the control plot of stand 23E6 in 1960 to 2001

– mean stand height,
– mean stand d.b.h.,
– stand basal area,
– growing stock,
– stand density and species composition.

Particular species in the stand have been recorded and summarized already from a height class of 2 m and d.b.h. 1 cm.

In making up and assessing evaluation criteria the following procedures were selected:

Table 2b. The development of beech frequency in height classes (m) and **mortality** in the control plot of stand 23E6 (0.20 ha) in 1960–2001

Height class (m)	1960	**1960 to 1967**	1967	**1967 to 1971**	1971	**1971 to 1976**	1976	**1976 to 1996**	1996	**1996 to 2001**	2001
3	10	**8**	1		1		1	**1**			
4	28	**16**	7	**5**	2	**2**					
5	23	**9**	7	**6**							
6	26	**9**	8	**5**	2	**1**					1
7	43	**1**	13	**10**	3	**1**	3	**3**			
8	44	**1**	14	**8**	5	**1**	2	**2**			
9	32		21	**5**	6	**1**	5	**3**	2	**2**	
10	10		33	**2**	10	**3**	6	**5**			
11	1		29		11	**1**	9	**6**	3		1
12	1		23		23	**1**	14	**9**	4	**2**	1
13			14	**1**	15	**2**	12	**10**	3	**1**	2
14			2		19		12	**6**	2		2
15			2		16	**1**	13	**6**	1		2
16					13		15	**3**	2		2
17					5		13		5	**1**	2
18					1		6	**1**	5		4
19							5		6	**1**	4
20							1		2	**1**	4
21									3		
22							1		1		1
23									8		5
24									5		5
25									3		5
26									3		3
27									1		3
28									2		6
29									2		1
30											1
Total	218	**44**	174	**42**	132	**14**	118	**55**	63	**8**	55
Per ha	1,090	**220**	870	**210**	660	**70**	590	**275**	315	**40**	275
Mean height	6.8	**4.6**	9.7	**7.0**	12.5	**9.4**	14.1	**12.0**	19.6	**13.9**	21.5

Mortality (expressed as a percentage of dead trees) in 5-year intervals of examination is always related to the frequency of previous measurements.

Growing stock and periodical volume increment derived from it are related to the main stand only; the volume of dead trees is not taken into account.

Stand density was calculated according to standard mensurational practices from the ratio of actual stand basal areas of particular species and table data. Based on reduced areas determined in this way species composition was also derived. To determine tabular basal areas mensurational tables were used (ÚHÚL 1990).

On the basis of the evaluation importance and proportion were assessed of spruce and beech on the production potential and stability of a tree component of the mixed stand under evaluation. Simultaneously, data were also obtained to fulfil the strategic targets of the project, viz. specification and presentation of a proposal (proposal variants) of the target species composition in the most important management groups (management sets of stands made up for forest management purposes and based on principles of forest typology) of upland/hilly regions, viz. for management groups HS 245 (or 255).

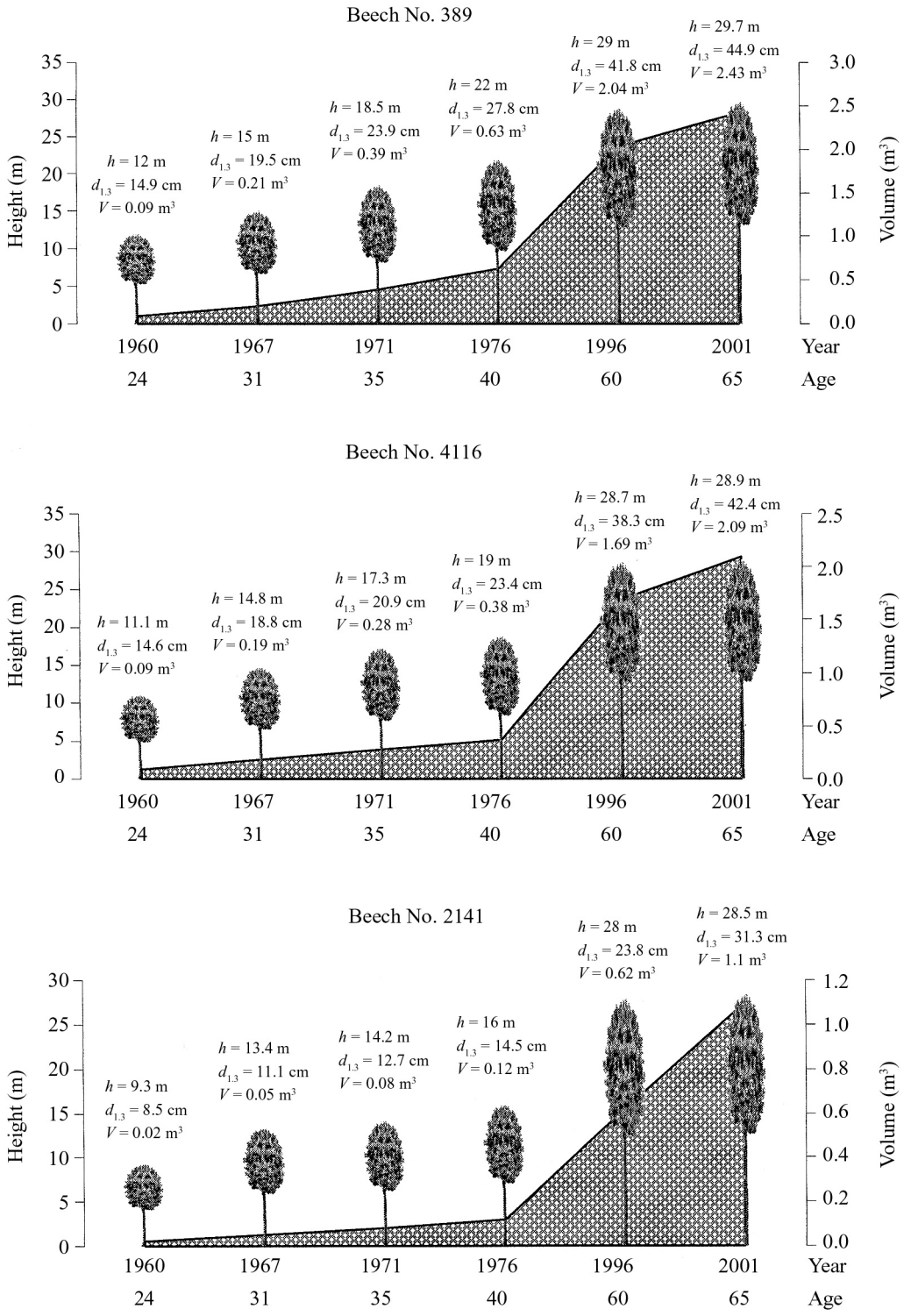

Fig. 2b. Development of beech trees of the largest volume in the control plot of stand 23E6 in 1960 to 2001

RESULTS OF STUDIES. ANALYSIS OF THE NATURAL DEVELOPMENT OF STAND 23E6

Basic characteristics of the control plot of Stand 23E6 in the year of establishment (1960) is given in Table 1. At that time (stand age 24 years), it was a silviculturally neglected dense spruce thicket to a small pole-stage stand with admixed beech and other interspersed tree species. The stand was characterized as fully-stocked (1.1) with stand basal area of 24.2 m^2/ha and growing stock 109 m^3/ha.

Stand density and mortality

Considerably high density in the stand age of 24 years, at the time of establishing the experiment (4,630 trees/ha) documents minimum silvicultural care in the stage of

Table 3a. The development of Norway spruce frequency in diameter classes (cm) and **mortality** in the control plot of stand 23E6 (0.20 ha) in 1960–2001

Diameter class (cm)	1960	**1960 to 1967**	1967	**1967 to 1971**	1971	**1971 to 1976**	1976	**1976 to 1996**	1996	**1996 to 2001**	2001
2	37	**30**	4	**3**	1	**1**					
4	60	**44**	18	**16**	2	**1**	1	**1**			
6	92	**33**	53	**45**	5	**4**	1	**1**			
8	110	**7**	75	**40**	37	**17**	19	**19**			
10	99	**1**	86	**13**	52	**13**	32	**30**	1	**1**	
12	76		54	**1**	43	**1**	45	**38**	6	**5**	1
14	42		62		54	**1**	43	**28**	2		2
16	8		42		46		43	**15**	14	**8**	5
18	7		12		35		34	**4**	15	**3**	10
20	3		7		10		20		14	**1**	10
22	1		6		9		9	**2**	18		15
24			1		6		10	**1**	21	**2**	16
26							5		8	**1**	12
28					2				8		8
30							2		5		7
32									10		6
34									1		6
36									0		3
38									2		1
40									0		1
42									0		1
44									1		
50									0		1
Total	535	**115**	420	**118**	302	**38**	264	**139**	126	**21**	105
Per ha	2,675	**575**	2,100	**590**	1,510	**190**	1,320	**695**	630	**105**	525
Mean height	8.6	**4.3**	11.0	**6.8**	13.6	**8.5**	15.0	**12.2**	22.6	**16.5**	25.1

thickets and small pole-stage stands when obviously dead trees only were removed.

Due to natural development and in consequence of competition relations the stand density gradually decreased (see Fig. 1) and at the last inventory at an age of 65 years in 2001, 910 trees/ha were recorded in the control plot. Thus, the total mortality amounted to 80% during 41 years while decrease in stand density was balanced in the course of the whole time series. It is of interest that the natural mortality of allochthonous spruce (about 80%) was only slightly higher than the mortality of autochthonous beech (about 75%) (Fig. 1).

Number of species in height and diameter classes

The development of frequency of spruce and beech in height classes in the course of 1960 to 2001 is given in Tables 2a and 2b, that in diameter classes in Tables 3a and 3b. The surveys also show the distribution of dead trees in relation to their height or d.b.h.

At the first measurement, the range of heights in spruce varied between 2 and 15 m, at the last measurement in 2001 between 17 and 33 m. Diameters of spruce ranged from 2 to 22 cm in 1960, from 12 to 50 cm in 2001. Based on the data but particularly from Tables 2a and 3a it is evident that in the course of the time series particularly subdominant trees of the smallest diameters died. Spruce trees occurring as co-dominant trees died quite exceptionally but mortality of dominant trees was not noticed at all.

Similarly as spruce also beech was markedly differentiated in its height in the time of starting the experiment (3–12 m). At the same time, the majority of beech trees ranked among smallwood (below 7 cm d.b.h. in Europe). Most of subdominant/intermediate/suppressed extremely slender trees gradually died, nevertheless, in the course of last inventory, even 20% beech trees occurring as 6 to 16 m tall subdominant trees survived.

Due to the facts, mean height of beech (21.5 m) was 4 m lower in 2001 as compared with mean height of spruce (25.9 m).

Table 3b. The development of beech frequency in diameter classes (cm) and **mortality** in the control plot of stand 23E6 (0.20 ha) in 1960–2001

Diameter class (cm)	1960	**1960 to 1967**	1967	**1967 to 1971**	1971	**1971 to 1976**	1976	**1976 to 1996**	1996	**1996 to 2001**	2001
2	73	**40**	28	**22**	6	**4**	2	**2**			
4	57	**4**	51	**17**	30	**6**	23	**19**	3	**3**	
6	48		33	**2**	32	**4**	26	**18**	6	**2**	2
8	28		31	**1**	14		14	**11**	5		6
10	10		15		21		14	**3**	3	**1**	2
12			13		15		13		10	**1**	10
14	2		1		9		15	**1**	5		2
16					3		7		4	**1**	6
18			1				2	**1**	2		
20			1		1				4		2
22									6		4
24					1		1		5		7
26									4		2
28							1		4		5
30											3
32											2
38									1		
42									1		1
44											1
Total	218	**44**	174	**42**	132	**14**	118	**55**	63	**8**	55
Per ha	1,090	**220**	870	**210**	660	**70**	590	**275**	315	**40**	275
Mean height	4.6	**2.2**	6.2	**3.1**	8.0	**4.0**	9.1	**6.1**	16.4	**7.8**	19.2

Thus, in the mixed stand, spruce dominated quite definitely as co-dominant and dominant tree species (77% spruce trees were at least 25 m tall); beech occurred rather as an intermediate tree (35% beech trees ≥ 25 m tall).

Stand basal area

The development of stand basal area (b.a.) of naturally developing stands objectively documents their production potential. Thus, in mixed stands, it is possible to evaluate separately each of the species and, at the same time, it is possible to assess silvicultural effectiveness and suitability of particular types of mixtures. Data on the development of b.a. in the course of the whole period are given in Table 4.

In the spruce/beech stand, an increase in b.a. was recorded from 24.2 m^2/ha at an age of 24 years by nearly 80% to 43.2 m^2/ha at an age of 65 years spruce basal area increasing from 18.3 to 27.7 m^2/ha (increase by 9.4 m^2/ha, i.e. by 51%) and that of beech from 2.4 to 10.1 m^2/ha (increase by 7.7 m^2/ha, i.e. by 320%).

Diametrically different input position of both species does not make possible to compare relative data, nevertheless, it is evident that beech can be evaluated in the mixture as an exceptionally "plastic" species with a markedly high production potential.

As for interspersed species, also larch preserved its position with a regular increase in b.a.

Growing stock of the main stand

The original growing stock of the experimental stand amounting to 109 m^3/ha increased within 41 years 5.1 times to a value of 560 m^3 (see Table 5). As mentioned in methodology, these data refer particularly to the main stand and the stock of dead and then felled trees has not been included there.

A periodical volume increment of the main stand culminated at an age of 31 to 35 years, however, even in the course of last inventories in 1996 and 2001, it reached a high value of 12.8 m^3/ha/year.

Production in the stand is based on the production of spruce which increased from 86 m^3/ha in 1960 to 370 m^3/ha 41 years later. These values are significantly completed by the dynamic increase in the beech growing stock (8 m^3/ha in 1960 but even 120 m^3/ha in 2001). As for interspersed species, particularly larch occurs in the basic spruce/beech mixture (see Tables 4 and 5).

Table 4. The development of stand 23E6 basal area (m^2/ha) and **its increase in per cent** in 1960–2001

Species	1960 age 24 year	1967 age 31 year	1971 age 35 year	1976 age 40 year	1996 age 60 year	2001 age 65 year	Increase with respect to 1960	
							absolute	**(%)**
Norway spruce	18.2734	22.5364	24.1013	25.4191	26.9305	27.6673	9.3939	**51.4**
Beech	2.4003	3.3896	4.1199	4.8150	8.3424	10.0778	7.6775	**319.9**
Pine	1.3476	1.6485	1.7190	1.8954	1.3591	0.9120	–0.4355	**–32.3**
Larch	1.1409	1.4315	1.5529	1.7436	2.2963	2.3591	1.2181	**106.8**
Oak	0.7230	0.9430	1.0127	1.2008	1.2477	1.3786	0.6557	**90.7**
Birch	0.1658	0.1254	0.0186				–0.1658	**–100.0**
Hornbeam	0.1795	0.2750	0.3790	0.4215	0.7126	0.7616	0.5821	**324.3**
Total	24.2305	30.3495	32.9033	35.4954	40.8886	43.1565	18.9260	**78.1**

Production potential of both main species of the mixed stand is illustrated in Figs. 2a and 2b depicting the development of three spruce and beech trees of the largest volume in the course of the whole time series of 41 years.

Stand density and species composition

Data on the development of stocking and species composition in the course of the time series are given in Tables 1 and 5.

Based on the data it is evident that stand density is maintained at a value of ±1.1 within the whole period under study. It means that permanently full stocking documents the optimum development of the spruce/beech ecosystem with natural mortality of suppressed and competition-unable components of the stand.

As mentioned above, the main production species of the stand is spruce. Its original proportion (71%) decreased to 56% in the course of 41 years, however, at present, its position appears to be stabilized. On the contrary, the proportion of beech gradually increased from original 13% it reached 31% in 2001.

CONCLUSION

Analysis of growth and development of the assessed mixed spruce/beech stand 23E6 in 1960 to 2001 (stand age 24 to 65 years), Forest District Vranov, Training Forest Enterprise Křtiny, confirmed its high production potential and the adequate rate of stability.

This important statement is based on the constant increase in basic production parameters (stand basal area, growing stock), permanently full stocking and the natural rate of mortality of suppressed and competition-unable stand components.

In the course of 41 years, the proportion of spruce in the stand without intentional thinning measures decreased from 71 to 56% and vice versa, beech proportion increased from 13 to 31%. At the same time, present position of spruce as dominant and co-dominant trees in the stand, its health condition and development in recent years indicate that the forest ecosystem under evaluation is stabilized and fulfils all its functions at an age of 65 years.

Thus, on the basis of results obtained, spruce with beech or beech with spruce can be considered to be a

Table 5. The development of growing stock 23E6 (m^3/ha) and stand density in 1960–2001

Species	1960 age 24 year	1967 age 31 year	1971 age 35 year	1976 age 40 year	1996 age 60 year	2001 age 65 year
Norway spruce	86.18	149.71	211.91	248.48	344.48	369.98
Beech	8.11	16.70	25.49	34.80	94.26	119.64
Pine	6.48	10.65	13.05	15.65	14.75	10.80
Larch	4.90	9.60	13.10	16.15	29.90	34.35
Oak	2.16	4.16	6.72	9.35	14.50	16.90
Birch	0.95	1.85	3.20	3.95	7.80	8.65
Hornbeam	0.64	0.68	0.10			
Total	109.42	193.34	273.57	328.39	505.69	560.32
Stand density	**1.06**	**1.15**	**1.09**	**1.11**	**1.10**	**1.11**

basis of one of the variants of target species composition even in "management groups of stands" 25 and 45 in hilly and upland regions. From the viewpoint of the climate development uncertainty and the principle of preliminary caution it is more useful to establish the stands as single-tree or clump (group) mixtures. The target species composition of spruce should not usually exceed 50%.

References

AHBE C.-J. et al., 1996. Förderung und Pflege von Buchen- und Buchenmischbestockungen. AFZ/Der Wald, *51*: 479–584.

BRAUN G., 1991. Die Bewältigung der Sturmkatastrophe 1990 aus der Sicht eines bayerischen Forstamtsleiters. Österr. Forstztg., *102* (11): 18–22.

DIMITRI L., 1987. Sind die Buchen-Fichten-Mischbestände stabiler als Reinbestände dieser Baumarten? Jahresbericht Hess. Forstverein: 45–60.

HÄBERLE W., 1997. Begründung naturnaher Fichten-Tannen--Buchen-Wälder. AFZ/Der Wald, *52*: 1302–1303.

HASENAUER H. et al., 1995. Ein Programm zur Modellierung von Wachstumsreaktionen. AFZ, *50*: 216–218.

HEINZE M. et al., 2001. Vergleich von Rot-Buche (*Fagus sylvatica* L.) in sogenannten Grünen Augen mit benachbarten standortsgleichen Fichtenbeständen (*Picea abies* /L./ Karst.) des Thüringer Vogtlandes bezüglich Eigenschaften und Durchwurzelung des Bodens sowie Baumwachstum. Forstw. Cbl., *120*: 139–153.

HILLEBRAND K., 1997. Simulation waldbaulicher Eingriffsfolgen für Buchen- und Fichten-Mischbestände mit Vogelbeere. AFZ/Der Wald, *52*: 535–538.

CHADT J.E., 1922. Pomíšení lesů v dobách dřívějších. Lesn. Práce, *1*: 411–414.

JELÍNEK P., KANTOR P., 2001. Production potential and ecological stability of mixed forest stands in uplands – IV. A mixed spruce/pine stand in the forest type group 2S (fresh, nutrient-medium beech-oak stand). J. For. Sci., *47*: 529–544.

KANTOR P., 1981. Vliv buku na produkci smrkových porostů v horských polohách. Zpr. Lesn. Výzk., *26* (2): 7–11.

KANTOR, P., 1997. Produkce a ekologická stabilita smíšených lesních porostů v antropicky se měnících podmínkách pahorkatin jako podklad pro návrh cílové skladby dřevin. Lesnictví-Forestry, *43*: 220–229.

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 an eutrophic site of the Křtiny Training Forest Enterprise. J. For. Sci., *47*: 45–59.

KANTOR P., PAŘÍK T., 1998. Produkční potenciál a ekologická stabilita smíšených lesních porostů v pahorkatinách: I. Jehličnatý porost s příměsí buku na kyselém stanovišti ŠLP Křtiny. Lesnictví-Forestry, *44*: 488–505.

KENK G., 2002. Variation der periodischen Zuwächse von Fichten und Buchen in Baden-Württemberg. AFZ-Der Wald, *57*: 300–302.

KNOTT R., KANTOR P., 2000. Produkční potenciál a ekologická stabilita smíšených lesních porostů v pahorkatinách: II. Bukojedlový porost na svěžím stanovišti ŠLP Křtiny. J. For. Sci., *46*: 61–75.

KONŠEL J., 1924. Porosty smíšené. Lesn. Práce, *3*: 2–6.

KORPEĽ Š., 1981. Zvyšovanie a zlepšovanie produkcie bukových prírastov smreka. Lesnictví, *27*: 47–70.

KOŠULIČ M., 1992. K zakládání smíšeného lesa v hospodářských souborech smrkového hospodářství. Lesn. Práce, *71*: 291–296.

KRISCHL W., MÜLLER F., 1988. Mischwuchsregulierung von Fichte und Buche in der Jungbestandphase. FBVA, Berichte 29: 1–50.

METTIN CH., 1986. Inwieweit ist Laubstreu eine ökologische und ökonomische Hilfe in Nadelholzbeständen? Allg. Forstz., *41*: 918–922.

NÜSSLEIN S., 1993. Fichten-Buchen-Mischbestand im Leistungsvergleich. AFZ, *48*: 682–684.

OTTO H.J., 1986. Standörtliche Voraussetzungen, Ziele und Waldbautechnik in Fichten-Buchen-Mischbeständen des Harzes. Teil II: Ziele, Möglichkeiten und Waldbautechnik von Mischbeständen der Fichte und Buche im Harz. Allg. Forst- Jagdztg, *157*: 214–222.

PODRÁZSKÝ V., 1996. Vývoj půdního chemismu v bukových, smíšených a smrkových porostech Krkonoš. Lesnictví-Forestry, *42*: 92–99.

PRETZSCH H., 1992. Modellierung der Kronenkonkurrenz von Fichte und Buche in Rein- und Mischbestände. Allg. Forst-Jagdztg, *163*: 203–213.

PRETZSCH H., 2000. From yield tables to simulation models for pure and mixed stands. J. For. Sci., *46*: 97–113.

PRETZSCH H., KAHN M., 1996. Variantenstudie Fichtenreinbestand versus Fichten/Buchen-Mischbestand. AFZ/Der Wald, *51*: 1415–1419.

RIEDER A., 1997. Bemerkungen zur Zielstärkennutzung. AFZ/Der Wald, *52*: 76–78.

ROTHE A., KREUTZER K., 1998. Wechselwirkungen zwischen Fichte und Buche im Mischbestand. AFZ/Der Wald, *53*: 784–787.

SANIGA M., 1990. Medzidruhová a vnútrodruhová konkurencia smreka a buka v rastovej fáze mladiny. Lesn. Čas., *36*: 553–561.

SANIGA M., 1994. Vplyv rozdielnej východiskovej hustoty na štruktúru a rastové ukazovatele smrekovcovo-bukovej mladiny. Lesn. Čas. – Forestry Journal, *40*: 353–361.

SEIBT G., 1982. Zum Wachstum von Buche und Fichte im Solling. Forst- u. Holzwirt, *37*: 570–571.

ŠINDELÁŘ J., 1997. Zakládání porostních směsí aneb o textuře lesních porostů. Lesn. Práce, *76*: 248–250.

ŠKODA B., 1925. Rozšíření dřevin a volba jejich s ohledem na stanoviště v lesní praxi. Lesn. Práce, *4*: 49–69.

ŠTEFANČÍK I., ŠTEFANČÍK L., 1998. Zhodnotenie vplyvu výchovy na zachovanie biodiverzity zmiešaných smrekovo--jedľovo-bukových porastov. Lesn. Čas., *44*: 485–501.

TRAUBOTH V., KRAUSS W., 1996. Weiterbehandlung der Fichte in den Wäldern Thüringens. AFZ/Der Wald, *51*: 489–491.

WEINFURTER P., 1988. Standortsbezogene Mischwaldbegründung. Österr. Forstztg., *99*: 28–29.

ZIMMERMANN H., 1988. Zur Mischung von Buche und Fichte auf Mittelgebirgsstandorten in Hessen. Forst u. Holz, *43*: 103–106.

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Produkční potenciál a ekologická stabilita smíšených lesních porostů v pahorkatinách – V. Smíšený smrkobukový porost na bohatém stanovišti ŠLP Křtiny

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ABSTRAKT: Studie je v pořadí pátým sdělením o produkčním potenciálu a stabilitě smíšených lesních porostů v pahorkatinách. Je v ní posuzován smrkobukový porost založený v polovině třicátých let 20. století. Porost leží v nadmořské výšce 470 m a je od roku 1960 ponechán samovolnému vývoji. V té době byl porost charakterizován jako pěstebně zanedbaná přehoustlá smrková mlazina až tyčkovina s přimíšeným bukem (zastoupení smrku 71 %, buku 13 %). V průběhu 41 let se v tomto porostu bez úmyslných probírkových zásahů snížilo zastoupení smrku ze 71 % na 56 %, naopak zastoupení buku vzrostlo z 13 % na 31 %. Současné úrovňové a nadúrovňové postavení smrku v daném porostu, jeho zdravotní stav i vývoj v posledních letech naznačují, že posuzovaný lesní ekosystém je na daném stanovišti ve věku 65 let stabilizovaný a plní všechny své funkce. Porost je trvale plně zakmeněný a jeho počáteční zásoba 109 m^3/ha ve věku 24 let v roce 1960 vzrostla na 560 m^3/ha ve věku 65 let v roce 2001.

Klíčová slova: smíšené porosty; smrk; buk; přirozený vývoj; produkce; přírůst; stabilita

V pořadí pátá studie rozsáhlého projektu *Produkční potenciál a ekologická stabilita smíšených lesních porostů v pahorkatinách* hodnotí smíšený porost smrku a buku na bohatém stanovišti 3. lesního vegetačního stupně. Jedná se o poměrně „jednoduchou“, avšak z produkčního i ekologického hlediska mimořádně významnou základní směs hlavních dřevin nejen horských a podhorských poloh, ale i pahorkatinných oblastí.

Postavení, vývoj, produkce a stabilita smrku i buku ve směsi s dalšími jehličnany byly analyzovány a publikovány v Lesnictví-Forestry v I. sdělení o řešení uvedeného projektu (KANTOR, PAŘÍK 1998). Smrk byl dále v rámci tohoto projektu hodnocen i ve smíšeném porostu s borovicí (IV. sdělení – JELÍNEK, KANTOR 2001).

V této studii hodnocený porost 23E6 byl založen po smýcení původních, vesměs buko-jedlových porostů v polovině třicátých let 20. století. Umělá obnova – výsadba převážně smrkových sazenic – byla v období vzniku nového porostu přirozeně doplněna pomístním jednotlivým, hloučkovitým až skupinkovitým zmlazením dalších dřevin, zejména buku.

Prvních 20 let byl porost ponechán víceméně přirozenému vývoji, odstraňovaly se z něj zejména odumřelé stromy. I tato skutečnost zde umožnila v roce 1960 založit výzkumné probírkové plochy v klasickém uspořádání podle tehdy platných metodických postupů katedry pěstování lesů Lesnické fakulty VŠZ v Brně.

Porost je situován na mírném východním až jihovýchodním svahu v nadmořské výšce 470 m. Jeho celková výměra činí 7,98 ha. Na podloží brněnské vyvřeliny – biotického granodioritu – se vytvořily půdy typu kambizemě typické – subtyp mezotrofní. Typologicky přísluší porost do lesního typu 3B2.

Na výzkumných plochách o rozloze 0,20 ha (vždy série pěti dílčích ploch 20 × 20 m) byly v období let 1960–1976 srovnávány podúrovňové a úrovňové zásahy s kontrolou ponechanou přirozenému vývoji, kde se odstraňují pouze odumřelé stromy. Studie shrnuje a hodnotí pouze tento přirozený vývoj porostu 23E6 na kontrolním dílci bez úmyslných zásahů, kde šetření průběžně pokračuje i po roce 1976, takže v současné době jsou k dispozici výsledky 41leté časové řady z let 1960–2001.

Metodika posouzení růstu a vývoje jednotlivých experimentálních porostů je v rámci celého výzkumného projektu jednotná a byla již publikována v Lesnictví-Forestry, resp. v Journal of Forest Science (KANTOR 1997; KANTOR, PAŘÍK 1998; KNOTT, KANTOR 2000; KANTOR et al. 2001; JELÍNEK, KANTOR 2001).

V době založení výzkumných ploch v roce 1960 byl porost 24letý, byl pěstebně zanedbaný, tloušťkově i výškově výrazně diferencovaný.

V druhovém složení dominoval smrk s přimíšeným bukem a dalšími vtroušenými dřevinami (borovice, modřín, dub, habr, bříza).

Produkční dřevinou posuzovaného porostu zůstává smrk. Jeho původní zastoupení (71 %) sice v průběhu 41 let pokleslo na 56 %, nicméně v současné době je jeho postavení stabilizované. Zastoupení buku naopak postupně narůstalo; z původních 13 % dosáhlo v roce 2001 hodnoty 31 %.

Současné úrovňové a nadúrovňové postavení smrku v daném porostu, jeho zdravotní stav i vývoj v posledních letech naznačují, že posuzovaný lesní ekosystém je na daném stanovišti ve věku 65 let stabilizovaný a plní všechny své funkce.

Toto významné konstatování se opírá o konstantní nárůst základních produkčních parametrů (kruhová výčetní základna, zásoba), o trvale plné zakmenění i přirozenou míru mortality potlačené a konkurence neschopné porostní složky. Konkrétní údaje o vývoji, produkci a mortalitě jednotlivých dřevin, resp. celého přirozeně se vyvíjejícího porostu lze vyčíst z tab. 1–5.

Smrk s bukem, popř. buk se smrkem tak lze i na základě předložených výsledků považovat za základ jedné z variant cílové druhové skladby i v hospodářských souborech 25 a 45 chlumních oblastí. Z pohledu nejistoty vývoje klimatu i principu předběžné opatrnosti je účelnější zakládat porosty jednotlivě, popř. hloučkovitě (skupinkovitě) smíšené, přičemž by zde cílové zastoupení smrku nemělo zpravidla překročit 50 %.

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