JOURNAL OF FOREST SCIENCE, *53*, 2007 (5): 193–203

Spontaneous hybrids within the genus *Abies* – growth and development

V. Janeček, J. Kobliha

Faculty of Forestry and Environment, Czech University of Life Sciences Prague, Prague, Czech Republic

ABSTRACT: Spontaneous hybrids within the genus *Abies* are considered to be better in growth and vitality in comparison with *Abies alba* and parental species. Three plantations with this material were established in the Czech Republic. These plantations are regularly measured and examined. The results show a very high potential of this material for the purposes of Czech forestry practice.

Keywords: genus *Abies*; hybridization

The silver fir (*Abies alba* Mill.) is one of our most important tree species, not only from economic but also from ecological aspects. High wood production connected with positive (indifferent) incidence at a site predetermines silver fir for utilization in our forests. Its importance decreased in the 20th century mainly because of its recession from Czech forests (and from forests of Central Europe generally). Its representation in Czech forests decreased from 19.8% (natural tree species composition) to 0.9%. Silver fir representation in the recommended tree specie composition of Czech forests should be 4.4% (Anonymous 2004). The viability of surviving local fir populations has also decreased. According to Forests of the Czech Republic (the company managing 60% of Czech forest land) there are 28 local populations on the edge of extinction. The number of silver fir trees in these populations has to be increased very soon (Indra 2002).

Its occurrence in our forests extremely decreased probably due to the following factors widely discussed in literature: the change in ecological conditions, different methods of management (preferring Norway spruce), lower genetic variability, high game stocks, air pollution pressure, parasite pressure, grazing restriction or phylogenetic age of this species.

There are three ways of solving the problem of silver fir decline. The first and the most important is *in situ* conservation connected with selection and reproduction of the most viable individuals. As an additional (but not marginal!) solution the introduction of other fir species and hybridization should be used.

According to Greguss et al. (1994a) there are eight spontaneous hybrids within the genus *Abies*. Spontaneous hybrids grow better compared with parental species. Present knowledge shows close affinity of some fir species and possibility of new hybrid origination.

Of course, scientists investigated very good growth and vitality. In 1868 the first artificial hybrid was obtained by Hugo de Vilmorin. It was *Abies cephalonica* × *Abies pinsapo*, named later as *Abies vilmorini*. This hybrid had a plenty of full and viable seeds (Paule 1992). It means that hybridization, especially interspecific one, is a verified way of increasing fir general resistance and viability (Greguss et al. 1994a). The hybrids within the genus *Abies* both from spontaneous and artificial hybridization distinguish themselves by heterosis from parental species not only in growth but also in increased viability. We can expect higher tolerance in fir hybrids in this aspect not only to various obligatory stress factors but also to possible consequences of changes in ecological conditions caused by the climate warming.

Rohmeder and Schönbach (1959) reported that interspecific hybrids of *Abies alba*, *Abies veitchii*,

Abies concolor, *Abies procera* and *Abies nordmanniana* grew faster than intraspecific hybrids. Mergen and Gregoire (1988) measured the height and diameter of 17-years-old hybrids that originated from crossing realized in 1960 and 1962 in Connecticut, USA. *Abies cephalonica*, *Abies firma*, *Abies homolepis*, *Abies koreana*, *Abies lasiocarpa*, *Abies mariesii*, *Abies procera*, *Abies sachalinensis* and *Abies recurvata* were used in this experiment. The results showed better growth and vitality compared to the control material (*Abies balsamea*). French researchers (Arbez et al. 1990) studied Mediterranean fir species and their hybridization. They recommended the utilization of fir progenies from selfing because of their inbreeding tolerance.

Kantor and Chira (1971) investigated fir hybridization in former Czechoslovakia using *Abies alba*, *Abies cephalonica*, *Abies nordmanniana*, *Abies pinsapo*, *Abies cilicica*, *Abies concolor*, *Abies grandis* for interspecific and intraspecific hybridization.

Greguss (1986, 1988a,b, 1992) and Kormuťák (1985, 1986, 1992) studied fir hybridization in Slovakia. Greguss (1986) reported slower growth of silver fir in comparison with fir hybrids and increasing differentiation between hybrid progenies and progenies of individual species from open pollination. Kormuťák (1986) presented similar results. He recommended primarily these combinations for planting in our conditions: *Abies alba* × *Abies cephalonica*, *Abies cephalonica* × *Abies numidica*, *Abies nordmanniana* × *Abies alba*, *Abies pinsapo* × *Abies cephalonica*, *Abies pinsapo* × *Abies alba*, *Abies numidica* × *Abies nordmanniana*, *Abies numidica* × *Abies cephalonica* and *Abies concolor* × *Abies grandis*. That means mainly the use of *Abies alba* and Mediterranean tree species. The same species already played the most important role in experiments of Kantor and Chira (1971) and Greguss (1988a,b, 1992, etc.).

MATERIAL AND METHODS

According to findings mentioned earlier comparative plantations with spontaneous hybrids within the genus *Abies* were established in the Czech Republic. There are three plantations there – one in Kostelec nad Černými lesy (Central Bohemia) and two in Forests of the Town of Prostějov (Central Moravia). They were established to evaluate possibilities of hybrid utilization in Czech forestry practice. Plantation characteristics are shown in Table 1.

The material on these plots originated from Kysihýbel' Arboretum in Slovakia. Seeds of spontaneous hybrids within the genus *Abies* were obtained there in 1990. Seeds were collected from 21 trees. Trees number 1–3 and 6–21 incline in phenotype to *Abies cephalonica*, tree number 4 to *Abies cilicica* and number 5 to *Abies numidica*. Table 2 shows the basic mother tree characteristics. These seeds were sown at Truba Tree Breeding Station of the Forestry Research Institute in Kostelec nad Černými lesy in spring 1991. Five (six) years old plants were used for the establishment of comparative plantations. *Abies alba* from open pollination was used as a control material.

The plantation in Kostelec nad Černými lesy was established in 1996. There are hybrids planted together with *Abies nordmanniana*, *Abies balsamea*, *Abies grandis*, *Abies procera*, *Abies concolor* and hybrid progeny of *Abies koreana* × (*Abies cilicica* × *Abies cephalonica*). All progenies are planted in blocks (replications) of 5 × 5 seedlings at a spacing of 1.2 × 1.2 m. The uneven number of seedlings is a result of damage caused by extreme humidity in 1996 which caused 100% mortality on a part of the plantation.

The first plantation in Prostějov was established also in 1996. All progenies are planted in blocks of 5 × 5 seedlings at a spacing of 1.5 × 1.5 m.

Table 1. Basic characteristics of the plots

Plot	Kostelec	Prostějov 1996	Prostějov 1997
Forest region	10	30	30
Forest altitudinal zone	2	3	4
Altitude (m a.s.l.)	380	480	530
Slope (%)	0	0	5
Bedrock	sandstone	sandstone	sandstone
Forest type	2K, 2I	3S	4K
Annual rainfall (mm)	682	802	802
Vegetation period rainfall (mm)	352	414	414
Average temperature (°C)	7.8	8.3	8.3
Vegetation period average temperature (°C)	16.2	17.8	17.8

Table 2. Table of mother trees in Kysihýbel' Arboretum, their progenies are planted on plots in Kostelec nad Černými lesy and Prostějov (Greguss, Longauer 1993)

Number of the plot	Number of the tree	$d_{1.3}$ (cm)	Height (m)	Number in comparative plantations
Abies cephalonica (Loud.) × ? Planted: 1910				
1–12	1	57	26.5	1
	2	49	26	2
	6	50	26.5	3
Abies cilicica (Carr.) × ? Planted: 1910/14				
1–14	3	43	26	4
Abies numidica × ? Planted: 1949				
1–64	13	35	21	5
Abies cephalonica (Loud.) × ? Planted: 1938				
4–6	6	28	22	6
	8	27	20	7
	17	32	22.5	8
	18	27	21	9
	40	30	24	10

The first and the second column are used for determination of the tree in Kysihýbel' Arboretum. The third and the fourth column show basic characteristics of the tree and the fifth column indicates the number of progeny in plantations

The second plantation in Prostějov was established a year later, in 1997. The conditions of this plantation are extremely dry. All progenies are planted in blocks of 5 × 5 seedlings at a spacing of 1.5 × 1.5 m. Spontaneous hybrids together with *Abies grandis* were planted there. The control material of *Abies alba* was planted a year later.

Measurements of this material were realized in 2002 and 2004 (and/or 2005) always after the vegetation period. Mortality was determined, and height was measured to the nearest 1 cm. The results were statistically processed – UNISTAT programme version 5.1. was used. The basic statistical characteristics were obtained. Analysis of variance was used for data testing. In the case of the absence of homogeneity of variance, non-parametrical Kruskal-Wallis test was used for data testing.

RESULTS

Mortality

Mortality in all plantations is shown in Fig. 1.

In Kostelec plantation average mortality was 30%. It ranged from 0% (*Abies nordmanniana*) to 52% (hybrid progeny 1). The mortality of the control material of *Abies alba* was 40%. Spontaneous hybrid progenies had average mortality of 29%. Low mortality (below 20%) was found in progenies 5, 6, 16, 18 and 20. The mortality of progenies 1, 3, 15, 21 was high (above 40%). Very low mortality was found in *Abies balsamea* – 6% and *Abies procera* – 4%. The hybrid *Abies koreana* × (*Abies cilicica* × *Abies cephalonica*) also had low mortality of 14% while the mortality of *Abies grandis* (40%) was very high.

In the plantation Prostějov 1996 the mortality increased up to 25% in 2005 in comparison with the year 2002, so there is a 1% change. High mortality over 30% was found in progenies 4 (34%), 9 (33%) and 16 (31%). Progenies 18 (10%), 2 (15%) and progeny mixture marked by × (18%) had very low mortality.

Average mortality in the plantation Prostějov 1997 was 24% in 2005. It ranged from 1% (progeny 7) to 60% (progeny 3). *Abies alba* mortality was 19% and the mortality of *Abies grandis* was 29%. Very low mortality was found also in progenies 6 (4%), 18 (6%) and 12 (11%). Very high mortality over 35% was recorded in progenies 3, 11, 15, 17 and 20.

Height

Fig. 2 shows mean heights of the material planted in Kostelec nad Černými lesy in 2002 and 2004. In 2002 the mean height of control material was 84 cm. All spontaneous hybrid progenies with the exception of one progeny exceeded the control material. Only

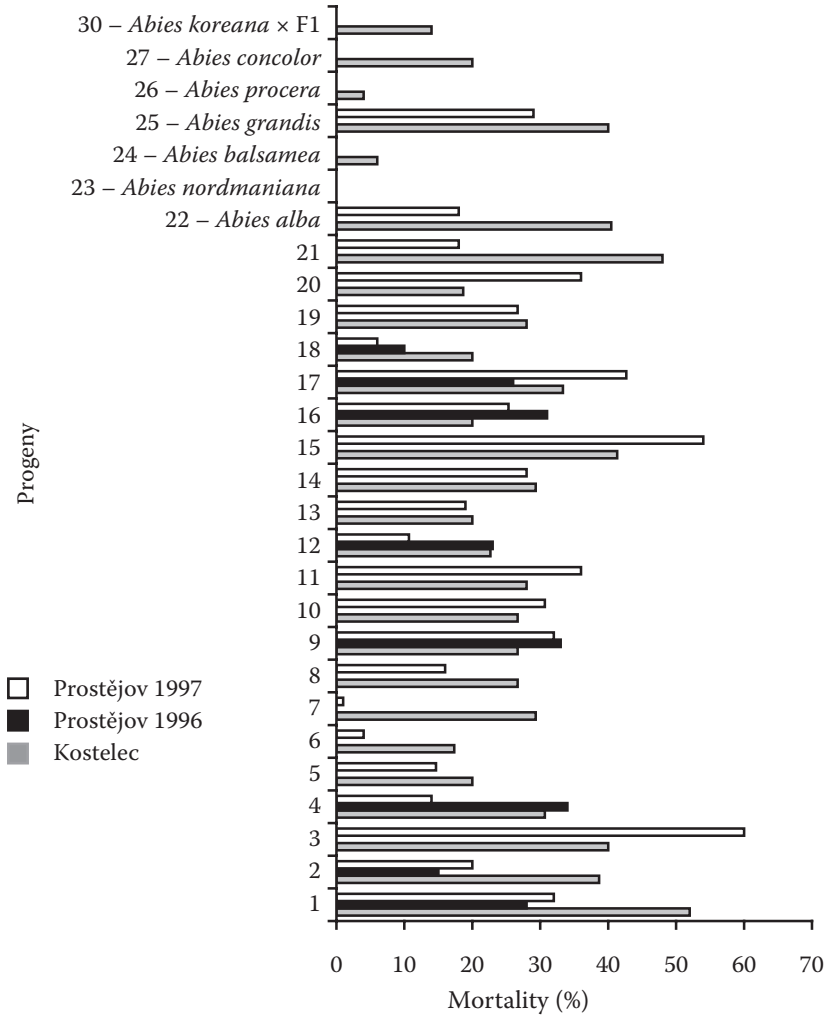

Fig. 1. Mortality in plantations with spontaneous hybrids

progeny number 16 with mean height 82 cm reached only 98% of the *Abies alba* height. The mean height of progenies was from 91 cm (progeny 2, 108% of *Abies alba* height) to 170 cm (progeny 8, 202% of *Abies alba* height). All introduced fir species exceeded *Abies alba*. *Abies grandis* reached mean height 144 cm (171% of *Abies alba* height), *Abies procera* 188 cm (223%), *Abies balsamea* 235 cm (279%), *Abies concolor* 239 cm (284%) and the absolutely highest was *Abies nordmanniana* – 339 cm (403%). The hybrid *Abies koreana* × (*Abies cilicica* × *Abies cephalonica*) reached the mean height of 118 cm (140% of *Abies alba* height).

The mean height in 2004 was 211 cm. Progeny 16 with mean height 130 cm (97% of *Abies alba* height) was the lowest of all again. The control material of *Abies alba* reached mean height 136 cm. The mean height of other progenies was from 143 cm (progeny 2, 105% of *Abies alba* height) to 276 cm (progeny 8, 203%). *Abies grandis* reached 233 cm (171% of *Abies alba* height), *Abies procera* 258 cm (190%), *Abies balsamea* 330 cm (243%), *Abies concolor* 335 cm (246%) and the highest was *Abies nordmanniana* – 450 cm (330%). The hybrid *Abies koreana* × (*Abies cilicica* × *Abies cephalonica*) reached the mean height of 160 cm (118% of *Abies alba* height).

Table 3 documents the results of Kruskal-Wallis analysis of variance. In both years there were significant differences in height between the progenies.

In the plantation Prostějov 1996 height was measured in 2002 (6 years after planting) and 2005 (9 years after planting). *Abies alba* as a control material is not planted there. In both years there were different numbers of particular progenies because of forest weeds and wrong labelling.

In 2002 mean height ranged from 95 cm (progeny 2) to 136 cm (progeny 17). Table 4 shows the results of ANOVA: there are no significant differences in height between the replications (the plantation is homogeneous), but there are significant differences between the progenies.

In 2005 mean height ranged from 153 cm (progeny 2) to 215 cm (progeny 17). Table 4 shows the results of ANOVA again: there are no significant differences in height between the replications but there

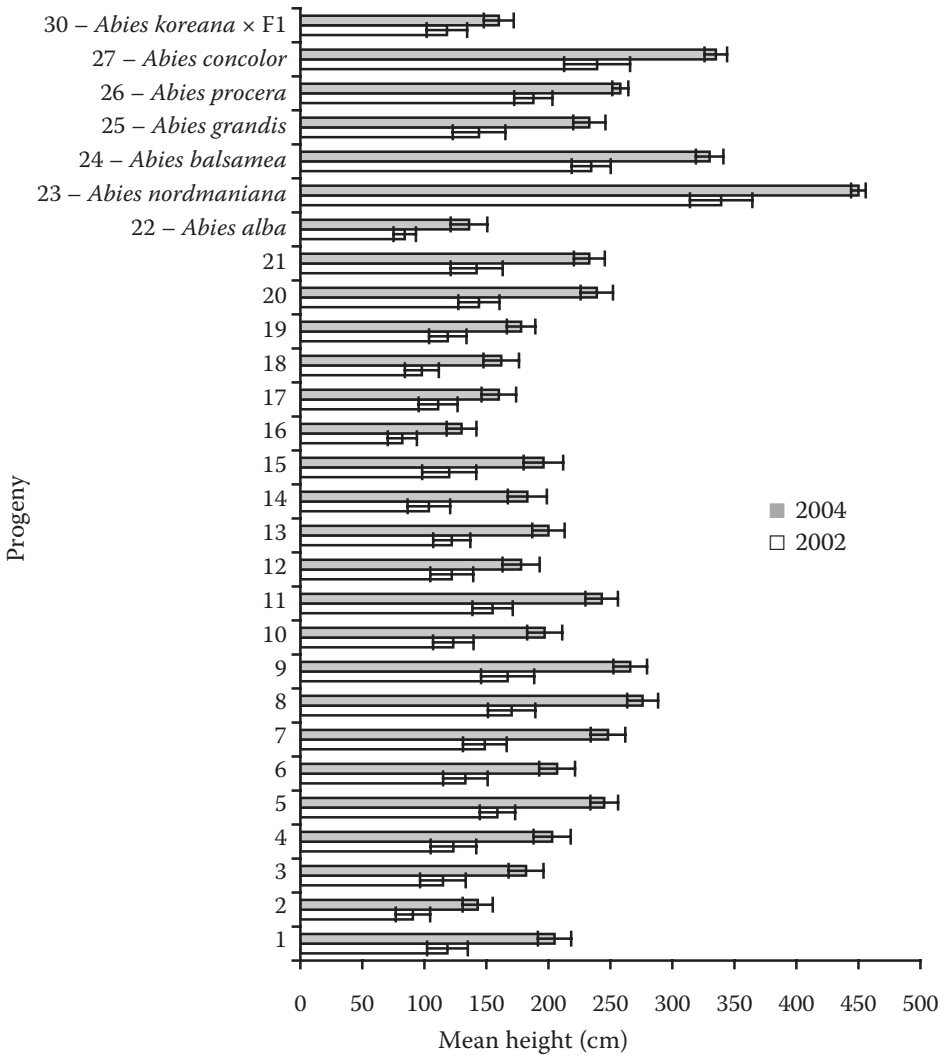

Fig. 2. The mean heights of material in Kostelec plantation in 2002 and 2004, vectors demarcate confidence interval 95%

are significant differences between the progenies. Fig. 3 illustrates mean heights of the material in the plantation Prostějov 1996 in 2002 and 2005.

In the plantation Prostějov 1997 height was measured also in 2002 and 2005. In 2002 the average height was 63 cm. The mean height of progenies ranged from 44 cm (progenies 15 and 18) to 78 cm (progeny 4). *Abies alba* reached mean height 75 cm and *Abies grandis* 106 cm. Fig. 4 shows mean heights of the material in the plantation Prostějov 1997 in 2002 and 2005.

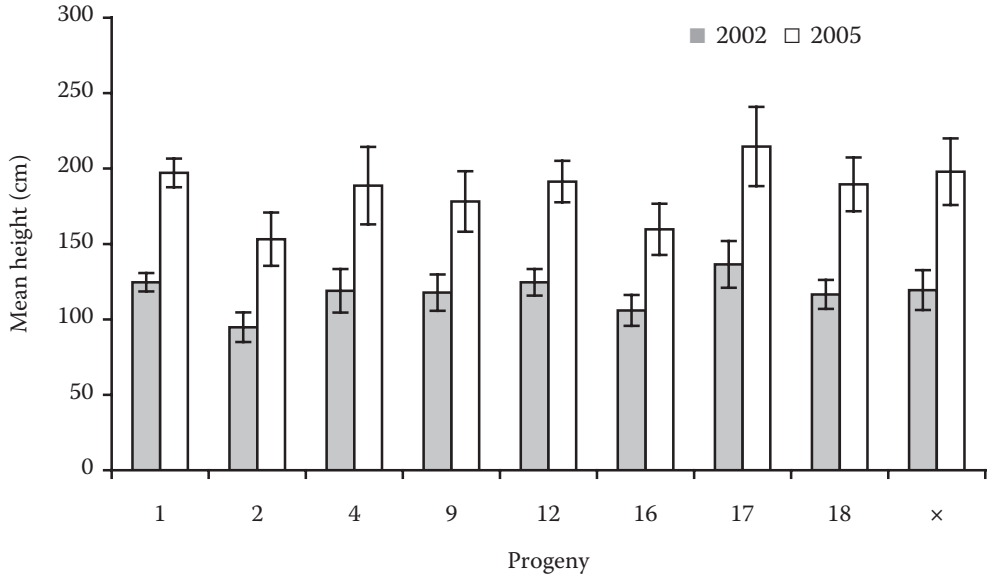

Fig. 3. The mean height in comparative plantation in Prostějov, 1996 (progenies mixture is marked ×, vectors demarcate confidence interval 95%)

Table 3. Results of Kruskal-Wallis analysis in Kostelec plantation, 2002 and 2004

Progeny	2002			2004		
	cases	rank sum.	mean rank	cases	rank sum.	mean rank
1	57	42,071	738	36	26,378	733
2	50	27,288	546	46	22,231	483
3	47	33,313	709	45	28,938	643
4	54	41,013	759	52	37,322	718
5	70	70,337	1,005	60	53,886	898
6	63	51,111	811	62	45,260	730
7	66	60,698	920	53	46,837	884
8	59	61,781	1,047	55	54,573	992
9	55	55,529	1,010	55	52,200	949
10	62	47,808	771	55	38,581	701
11	72	69,348	963	54	47,477	879
12	66	48,774	739	58	35,569	613
13	64	48,638	760	60	43,043	717
14	59	36,155	613	53	33,612	634
15	47	33,734	718	44	29,853	678
16	63	29,825	473	60	25,769	429
17	54	36,989	685	50	27,725	555
18	64	38,007	594	60	33,800	563
19	59	43,697	741	54	34,581	640
20	68	60,838	895	61	52,911	867
21	41	36,607	893	39	33,272	853
Abies alba	150	71,953	480	134	59,836	447
Abies nordmanniana	25	39,663	1,587	25	35,532	1,421
Abies balsamea	97	128,470	1,324	94	108,755	1,157
Abies grandis	32	29,416	919	30	25,387	846
Abies procera	24	29,227	1,218	24	23,417	976
Abies concolor	23	31,521	1,370	20	23,889	1,194
Abies koreana × F1	43	31,991	744	43	24,170	562
Total	1,634	1,335,795	818	1,486	1,104,841	744

Chi-square statistic = 445.4319 (2002); 407.2921 (2005)
Degrees of freedom = 27
Right-tail probability = 0.0000

The results of Kruskal-Wallis analysis of variance show significant differences in height between the progenies (see Table 5).

In 2005 height was measured again. The mean height in this plantation was 92 cm. The mean height of spontaneous hybrid progenies ranged from 56 cm (progeny 15) to 123 cm (progeny 4). *Abies alba* reached the mean height of 116 cm and *Abies grandis* 183 cm.

Table 5 documents the results of Kruskal-Wallis analysis of variance. It shows significant differences in height between the progenies.

DISCUSSION

Mortality

Mortality, especially in the first years after planting, is a big problem. The fir is one of the most sensitive tree species and that is why nearly all authors mentioned a very low survival rate. The results reported in literature differ in the different authors and also in one author. Hynek (1989) dealt with silver fir provenance research. He reported mortality on three plots in the Šumava region one year after

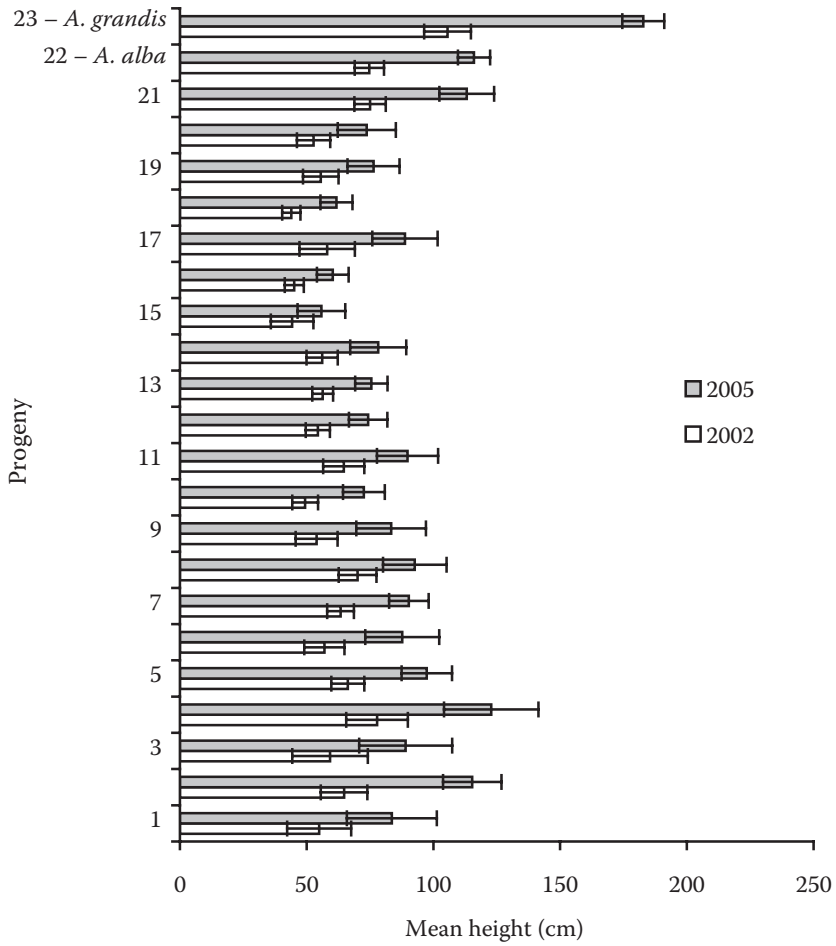

Fig. 4. The mean height in comparative plantation in Prostějov, 1997. The vectors demarcate confidence interval 95%

planting: plot 1 (Vimperk) – mortality 5%, 2 (Nýrsko) – 8%, 3 (Kašperské hory) – 57%. Higher mortality on the third plot was caused by higher elevation and unsuitable rainfall distribution during the vegetation period. Mortality was also affected by seedling age in the planting time. The seedlings planted at the age of six years had mortality up to 40%.

The highest mortality was observed in Kostelec (30%) due to a reason discussed later. Both plantations in Prostějov had lower mortality – 24 (25%).

Mortality in Kostelec was affected by waterlogging in 1996. This mortality had nothing to do with seedling origin, so it was not tested statistically. Dead seedlings were replaced by seedlings from the reserve in 1997.

In spring 1998 the mortality 22% was observed. Mortality was still concentrated to the part affected by waterlogging. Mainly seedlings planted in 1997 and seedlings considered in 1997 as withering died.

The planting of six years old (and older) seedlings is connected with high mortality (Hynek 1989). This presumption was confirmed in Kostelec plantation, where mortality was 30% (*Abies alba* 40%). In the part not affected by waterlogging mortality was

Table 4. ANOVA results – plantation Prostějov 1996, measured in 2002 and 2004

Variability source	2002					2005				
	sum of squares	degrees of freedom	mean square	stat. *F*	significance	sum of squares	degrees of freedom	mean square	stat. *F*	significance
Supplier	87	1	87	0.034	*0.8545*	9,661	1	9,661	1.417	*0.2343*
Replication	87	1	87	0.034	*0.8545*	9,661	1	9,661	1.417	*0.2343*
Main effect	90,784	8	11,348	4.392	*0.0000*	190,765	8	23,846	3.497	*0.0006*
Progeny	90,784	8	11,348	4.392	*0.0000*	190,765	8	23,846	3.497	*0.0006*
Explained	90,871	9	10,097	3.908	*0.0001*	200,426	9	22,270	3.266	*0.0006*
Error	2,206,653	854	2,584			5,816,643	853	6,819		
Total	2,297,524	863	2,662			6,017,069	862	6,980		

Table 5. Results of Kruskal-Wallis analysis in Prostějov 1997 plantation, measured in 2002 and 2005

Progeny	2002			2005		
	cases	rank sum.	mean rank	cases	rank sum.	mean rank
1	18	8,478	471	17	9,182	540
2	39	22,380	574	40	31,240	781
3	18	8,389	466	20	11,236	562
4	41	27,744	677	43	31,867	741
5	64	38,760	606	64	40,335	630
6	25	12,802	512	24	13,785	574
7	92	52,247	568	99	57,396	580
8	39	26,102	669	42	25,001	595
9	33	14,415	437	34	17,472	514
10	49	20,011	408	52	22,642	435
11	43	25,074	583	48	26,912	561
12	64	30,118	471	67	29,991	448
13	78	38,907	499	81	37,652	465
14	36	17,865	496	36	17,413	484
15	22	6,957	316	23	6,483	282
16	56	18,439	329	56	17,920	320
17	35	16,455	470	43	23,668	550
18	47	14,519	309	47	15,534	331
19	51	23,732	465	55	24,934	453
20	31	14,009	452	32	14,167	443
21	80	56,068	701	82	59,782	729
Abies alba	79	55,735	706	82	61,377	748
Abies grandis	51	46,485	911	53	54,387	1,026
Total	1,091	595,686	546	1,140	650,370	571

Chi-square statistic = 219.9190 (2002); 292.0128 (2005)
Degrees of freedom = 22
Right-tail probability = 0.0000

below ten percent, so we cannot draw a conclusion about higher mortality in comparison with spontaneous hybrid progenies.

Silver fir as a control material was also planted in Prostějov (established 1997). It had substandard mortality 19%. This is very important because this plot does not look suitable for silver fir planting due to very dry conditions. Silver fir was planted one year later there and that can be a reason for its lower mortality. The year 1997 was very dry and silver fir seedlings were planted in a nursery and planted in better climatic conditions in 1998.

According to Greguss et al. (1994b) the difference in survival rate between hybrids and control material rapidly increased in favour of hybrids. This presumption applied to the *Abies koreana* × (*Abies cilicica* × *Abies cephalonica*) hybrid with mortality 14% in Kostelec.

The mean mortality of spontaneous hybrid progenies originating from Kysihýbeľ Arboretum (numbers 1–21) and planted in Kostelec was 29%. Low mortality was observed in hybrids number 6, 16, 18 and 20 (below 20%). In Prostějov (1996) plantation mortality below 20% was observed in hybrids 2 and 18. In Prostějov (1997) hybrids 4–8, 12, 13, 18 and 21 showed very low mortality. The most vital hybrids of all were hybrid 6 (it is not planted in Prostějov 1996 plantation) and 18 with mortality only 11 and 12%, respectively.

High mortality (above 30%) in Kostelec was recorded in hybrids 1–4, 15, 17 and 21, in Prostějov (1996) in hybrids 4, 9 and 16, and in Prostějov (1997) in hybrids 1, 3, 9, 10, 11, 15, 17 and 20. The highest mortality of all was found out in hybrid 3 (50%) followed by hybrids 15 (48%), 1 (37%), 17 (34%) and 21 (33%).

The mortality after planting is not probably connected with mortality in a nursery. Between the years 1994 and 1996 more than 30% of four hybrid seedlings died. They were progenies 1, 6, 8 and 14. Only hybrid 1 has higher mortality after planting. Other progenies with higher mortality in the nursery show lower (below the mean of the plot) mortality after planting. On the contrary, progeny 19, which shows 9% mortality in the nursery, had 31% mortality after planting. This progeny is probably more sensitive to changing conditions and was heavily affected by waterlogging.

There are also North-American fir species in plantations. There are experiences with the planting of such tree species in Czech conditions, for example *Abies grandis* and *Abies concolor*. An IUFRO provenance trial with the North-American fir species *Abies grandis* and *Abies procera* was conducted in the Czech Republic. According to Vančura and Beran (1995) *Abies grandis* mortality was from 5 to 46%. This species is damaged by pests and waterlogging. *Abies procera* mortality is very high immediately after planting and there is only a small change in the following years. *Abies grandis* was planted on Kostelec and Prostějov 97 plots. The mortality in Kostelec (8 years after planting) is 40%, in Prostějov (7 years after planting) 29%. In comparison with the other progenies *Abies grandis* mortality is significantly higher than mean mortality. The mortality of this tree species is higher compared to Vančura and Beran (1995) results.

Abies concolor mortality on Kostelec plot is only 20%. Other authors reported significantly higher mortality of this tree species, e.g. Vančura (1990), Šindelář and Beran (2004), etc.

Abies nordmanniana mortality in Kostelec is 0%. This can be explained by a low number of seedlings – there are only 25 individuals on the plot. The mortality of *Abies balsamea* (6%) and *Abies procera* (4%) was very low. *Abies procera* results can be distorted by the very low number of seedlings again. There are four replications in *Abies balsamea* (100 seedlings). Its high viability confirms former results (Šindelář, Beran 2004).

Abies procera mortality was only 4% eight years after planting. There are only 25 seedlings on the plot, so the result can be distorted again. The mortality at the age of 8 (9) years is shown in Fig. 1.

Height

Many authors reported better growth of *Abies* hybrids compared to *Abies alba*. The analysis of variance shows high significance of the influence of progeny origin on height.

There is a relation between height and seedling age at the planting time. According to Hynek (1989) the mortality of older seedlings is significantly higher than that of younger seedlings (the age at the planting time). This tendency was observed in an *Abies alba* provenance trial in the Czech Republic 15 years after planting.

Greguss (1992) mentioned increasing height differences between fir hybrids and parental tree species.

In 1998 the Kostelec plantation was measured. The mean height of the material was 34 cm. *Abies alba* reached the mean diameter of 27 cm. Spontaneous hybrids 1–21 reached the mean height from 22 cm (progeny 2, the only one with lower height compared to *Abies alba*) to 45 cm (progeny 9, 167% of the *Abies alba* mean height). All non-native fir species exceeded the control material – *Abies grandis* 36 cm (133% of the *Abies alba* mean height), *Abies procera* 53 cm (196%), *Abies concolor* 60 cm (222%), *Abies balsamea* 62 cm (230%) and the highest was *Abies nordmanniana* 104 cm (385%). The analysis of variance shows significant differences between progenies and also between replications. This can be caused by plot heterogeneity due to waterlogging in 1996–1998. Measurements in 2002 and 2004 (Fig. 2) showed better growth of hybrid material compared to *Abies alba*.

Greguss (1992) reported higher wood production of fir hybrids compared to *Abies alba* and non-native fir species. This measurement was realized in Kysihýbeľ Arboretum at the age of around 30 years. We cannot confirm this result due to the young age of our material. Hybrid firs show different growth dynamics, so future measurements are needed.

If we compare the height of the progenies with progeny height in the nursery in 1995, we can see that the growth tendency is still nearly similar. With only few exceptions the order of progenies is the same. The highest progeny in the nursery was progeny 9, one of the highest in the last measurement. The lowest in the nursery was progeny 2, which is still the lowest at the present time.

Very good growth of *Abies nordmanniana* in the first years after planting is also mentioned in literature. Greguss (1992) reported that this tree species reached 113.9% of the mean height of all material at the age of one year, at the age of ten this species is the lowest one. Our results show increasing differences between this material and others. At the age of 8 years *Abies nordmanniana* is absolutely the best with 330% of the *Abies alba* mean height.

In the plantation Prostějov 96 the lowest progeny was progeny 2, which is the same progeny as in Kostelec plantation. The highest progeny from Kostelec, progeny 5, is not planted there, the highest progeny, No. 9, is in Kostelec plantation around the mean of the whole plantation.

In the plantation Prostějov 97 the lowest progeny was progeny 15 (in Kostelec plantation around the plantation mean). The highest progeny (No. 4) is again around the mean in Kostelec and Prostějov 97 plantations. In this plantation very good growth of silver fir is surprising. This can be explained by its later planting (the year 1997 was very dry, the next year was climatically better for fir planting). We can assume better growth of hybrid progenies in future.

CONCLUSION

European silver fir (*Abies alba* Mill.) was one of the most important tree species in Czech forests. Its occurrence extremely decreased in the last century and the vitality of trees in surviving local populations also diminished. Silver fir is an important tree species because of higher production ability than in Norway spruce (*Picea abies* [L.] Karst.) and high ecological importance as well.

European silver fir is one of those domestic tree species the maintenance of which is done especially by its resistance. Fir cannot be bred for specific resistance like elms. That is why breeding has to be directed to an increase in general resistance.

One of the important approaches for increasing fir resistance by breeding is interspecific hybridization because it is known that hybrids within the genus *Abies* often reach the effect of heterosis not only in growth but also in increased vitality in comparison with parental species. Higher tolerance to various stress factors including the air pollution pressure is connected (and possibly higher tolerance to the expected climate warming).

Spontaneous hybrids within the genus *Abies* are mostly better in growth and vitality than the control material of *Abies alba* from open pollination. All plantations are still very young, so regular measurements should continue.

The material can be used for special plantations, especially where local silver fir populations are extinct and on anthropogenically destroyed plots (after mining and so on). Changing climate conditions should be considered. This material can also be used as Christmas trees.

All these results show a high potential for Czech forestry practice. There is also a high potential for future breeding. Vegetative reproduction of this hybrid material is an important problem to solve.

References

ANONYMOUS, 2004. Zpráva o stavu lesa a lesního hospodářství České republiky. Praha, Ministerstvo zemědělství ČR: 107.

ARBEZ M., FADY B., FERRANDES P., 1990. Variabilite et amelioration genetique des sapins mediterranneens – Cas du sapin de Cephalonie (*Abies cephalonica* Loud.). In: International Workshop Mediterranean Firs – Adaptation, Selection and Silviculture, Avignon, France, 11.–15. 6. 1990: 43–57.

GREGUSS L., 1986. Šľachtiteľský program zvýšenia odolnosti jedle hybridizáciou. In: Zborník zo 7. celoštátnej semenársko-šľachtiteľskej konferencie. Spišská Nová Ves, MLVH SSR Bratislava: 34–41.

GREGUSS L., 1988a. Trvalá výskumná plocha hybridných jedlí Drieňová. [Exkurzný sprievodca.] Zvolen, VÚLH, VS Banská Štiavnica: 9.

GREGUSS L., 1988b. Medzidruhová hybridizácia – náhrada za ustupujúcu jedlu bielu. Lesnictví, *34*: 797–808.

GREGUSS L., 1992. Hodnotenie začiatočného rastu medzidruhových jedlových hybridov na príklade trvalej výskumnej plochy Drieňová. Lesnícky časopis – Forestry Journal, *38*: 223–238.

GREGUSS L., LONGAUER R., 1993. Lesnícke arborétum v Kysihýbli pri Banskej Štiavnici. [Stručný sprievodca.] Zvolen, LVÚ: 23.

GREGUSS L., LONGAUER R., KRAJŇÁKOVÁ J., 1994a. Progress in the breeding program of specific hybridization of firs (a review). In: Ergebnisse des 7. IUFRO-Tannensymposiums der WP S. 1.01-08 Ökologie und Waldbau der Weiβtanne. Altensteig, IUFRO: 144–154.

GREGUSS L., LONGAUER R., KRAJŇÁKOVÁ J., 1994b. Realizácia šľachtiteľského programu medzidruhovej hybridizácie jedlí. Spravodaj botanických záhrad, *44*: 83–91.

HYNEK V., 1989. Hodnocení provenienčních ploch s jedlí bělokorou na Šumavě. Práce VÚLHM, *74*: 207–238.

INDRA P., 2002. Podíl jedle bělokoré ve výhledových cílech obnovy lesa u LČR. Lesnická práce, *81*: 20–21.

KANTOR J., CHIRA E., 1971. On the possibility of crossing certain species of the genus *Abies*. Acta Universitatis Agriculturae, Facultatis Silviculturae, *40*: 15–27.

KORMUŤÁK A., 1985. Study on species hybridization within the genus *Abies*. SAV, Series Acta Dendrobiologica: 127.

KORMUŤÁK A., 1986. Výškový rast vybraných druhov cudzokrajných jedlí a ich hybridov. In: Zborník zo 7. celoštátnej semenársko-šľachtiteľskej konferencie. Spišská Nová Ves, MLVH SSR Bratislava: 123–131.

KORMUŤÁK A., 1992. Hybridizácia druhov *Abies concolor* (Gord. et Glend./Lindl.) a *Abies grandis* (Dougl./Lindl.) na Slovensku. Lesnictví-Forestry, *38*: 759–769.

MERGEN F., GREGOIRE T.G., 1988. Growth of hybrid fir trees in Connecticut. Silvae Genetica, *37*: 118–124.
PAULE L., 1992. Genetika a šľachtenie lesných drevín. Bratislava, Príroda: 304.
ROHMEDER E., SCHÖNBACH H., 1959. Genetik und Zuchtung der Waldbäume. Verlag Paul Parey, Berlin: 338.
ŠINDELÁŘ J., BERAN F., 2004. Srovnání druhů rodu *Abies* v lesích města Písku. Lesnická práce, *83*: 19–21.
VANČURA K., 1990. Provenienční pokus s jedlí obrovskou série IUFRO ve věku 13 let. Práce VÚLHM, *75*: 47–66.
VANČURA K., BERAN F., 1995. Výsledky pokusů IUFRO se severoamerickými jedlemi v ČR. Zpravodaj lesnického výzkumu, *40*: 1–6.

Received for publication September 18, 2006
Accepted after corrections December 4, 2006

Spontánní hybridy rodu *Abies* – růst a vývoj

ABSTRAKT: Spontánní hybridy rodu *Abies* předčí v rychlosti růstu i vitalitě jak domácí *Abies alba,* tak i rodičovské druhy. V České republice byly založeny tři výsadby s tímto materiálem. Jsou pravidelně měřeny a sledovány. Výsledky ukazují vysoký potenciál tohoto materiálu pro využití v lesnické praxi.

Klíčová slova: rod *Abies*; hybridizace

Corresponding author:

Ing. Vladimír Janeček, Ph.D., Česká zemědělská univerzita v Praze, Fakulta lesnická a environmentální,
165 21 Praha 6-Suchdol, Česká republika
tel.: + 420 224 383 787, fax: + 420 234 381 860, e-mail: janecekv@fle.czu.cz