

## GROWTH AND DEVELOPMENT OF FIR (*Abies alba* Mill.) IN MIXED SPRUCE, FIR AND BEECH STANDS

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### Abstract

Štefančík I.: Growth and development of fir (*Abies alba* Mill.) in mixed spruce, fir and beech stands. Ekológia (Bratislava), Vol. 23, No. 2, 144-151, 2004.

The paper deals with assessment of fir growth on four research plots in Slovakia situated in mixed spruce, fir and beech stands, where no interventions have been carried out during last 30 years. The results showed the high decrease of fir, which was 76–89% out of the number of trees. On the contrary, the highest proportion on each plot during investigation period has been registered for beech, which shifted into the dominant canopy layer whilst the middle canopy layer comprised of fir and spruce. As for mean crown width the low, as well as statistically insignificant differences among tree species were found. The crown width in relation to diameter increment of tree species was the closest on each plot for beech, and the correlation was found statistically significant ( $P < 0.01$ ), too. For fir and spruce, lower values of coefficient of correlation were found, while they were not always significant. The highest mean annual diameter increment was registered for spruce and the lowest for fir. The above-mentioned outcomes suggest that beech is characterized by strong competition ability in comparison to other tree species under the given ecological conditions.

**Key words:** mixed stand, spruce-fir-beech, growth parameters, Slovakia

### Introduction

Fir (*Abies alba* Mill.) belongs to the most important tree species under the natural conditions of Slovakia. Original proportion of fir in Slovak forests was 14.1%, but now it has decreased to only 4.5% (Vladovič et al., 1998).

According to the literature it is clear that the beginning of continuous fir dieback in the European area has been observed since the 18<sup>th</sup> century (Málek, 1983). Although, the research focused on fir tree species was carried out by many authors in the past, their opinions related to its decline are very different. Some authors consider the climatic effects, especially drought and lack of precipitation as a cause of these events (Becker, Lévy, 1988). Other authors attributed the importance to abiotic injurious factors (frost damages) to-

gether with insect and fungal pests and/or root decay (Courtois, 1983). Some papers emphasize the importance of soil moisture, water regime and supply of trees by soluble nutrients. A lot of authors have convinced that extensive fir dieback is due to air pollution (Encke, 1982; Krammer, 1982), which was generally considered especially since the 70's of the last century as one of the principal causes of "novel forest decline" in Europe. Besides of mentioned consequences, there have been published the papers related to impact of bad management methods of mixed fir forests and/or ecological properties of fir which were not taken into account in implementation of silvicultural intervention (Korpeľ, 1985).

However, it can be concluded that during the last decades the fir decrease have been registered practically in all European countries (Krammer, 1982; Málek, 1983; Encke, 1982; Korpeľ, 1985; Becker, Lévy, 1988).

The aim of this paper is to ascertain and compare the fir growth in mixed spruce, fir and beech stands in a 30-year period.

### Material and methods

As an object of our research were chosen the series of permanent research plots (PRP) located in the 5<sup>th</sup> and 6<sup>th</sup> forest altitudinal zone of Central Slovakia, established in the past by Prof. Ing. L. Štefančík, DrSc., for the research on production relations in mixed spruce, fir and beech stands. Each of PRP series usually consists of some partial plots where one of them is always as control (without any interventions). Other partial plots are managed for the purpose to compare intervention effects on individual tree species. The area of plots ranges from 0.20 to 0.50 hectare and its arrangement depends on field condition, and they are isolated from each other by a 10 m wide tree belt. The trees on all plots are numbered and measurement points at the breast height 1.3 m are marked out. Complex biometrical measurements are carried out on numbered trees in 5-year intervals in accordance with standard methods (Štefančík, 1977). Since the establishment of PRP, seven biometrical measurements have been carried out on all plots. Within their framework, the quantitative parameters – breast height diameter, tree height and crown size at horizontal projection were measured.

Experimental material of this paper results from four partial plots established in three geomorphologic units in Slovakia (Veľká Fatra Mts, Low Tatra Mts and Volovské vrchy Mts) in mixed spruce, fir and beech stands. A more detailed description of research plots is presented in Table 1. Data were processed by common biometrical and statistical methods according to standard methods for research. To find out the significance of influence of tree species on diameter increment and crown width the analysis of variance (ANOVA) was used.

The base of methodical procedure in processing of the results was to find the biometrical values on partial plots in the stage of their establishment and after the last measurement, what represents a period of 30 years. To exclude the influence of management on development of investigated parameters, we took into account only control plots, where no interventions were carried out. Ascertained values were compared among individual tree species.

### Results and discussion

Table 2 presents tree species composition on partial plots in the initial stage of research and after 30 years. As for spruce, fir and beech it can be seen that when research started, fir was the second proportioned tree species and on Motyčky PRP even the most frequent one.

Characteristic	PRP Motyčky	PRP Korytnica I, II, III	PRP Hrable
Establishment of PRP (year)	1971	1967	1968
Age of stand (years)	spruce 46, fir 41, beech 48	spruce 58, fir 50, beech 50	spruce 80, fir 82, beech 74
Geomorphologic unit	Veľká Fatra Mts	Nízke Tatry Mts (west part)	Volovské vrchy Mts
Exposition	NE	NE	W
Altitude [m]	810-870	930-970	820-840
Inclination (degree)	30	30-35	25
Parent rock	Dolomite	Triassic Schist	phyllite and quartzite slope deposits
Soil unit	Rendzic Leptosol/Calcaric Cambisol	Cambisol/Umbic Leptosol	Haplic Cambisol/Dystic Cambisol
Altitudinal forest zone	5 <sup>th</sup> fir - beech	6 <sup>th</sup> spruce-beech-fir	5 <sup>th</sup> fir-beech
Ecological rank	B/C	B/C	B
Management complex	55	65	55
Management complex of forest types	511 fertile fir-beechwoods	611 fertile beech-fir sprucewoods	511 fertile fir-beechwoods
Forest type group	<i>Fageto-Aceretum</i> (FAC) n.st.	<i>Fageto-Aceretum</i> (FAC) v.st.	<i>Abieto-Fagetum</i> (AF) n.st.
Forest type	5401 mercury-beech maplewoods	6402 fern-beech maplewoods	5301 low-herbaceous fir beechwoods
	n.st.	v.st.	n.st.
Average annual temperature [°C]	5.8	4.2	6.0
Average annual precipitation sum [mm/year]	1.085	1.200	900

After 30-year period, certain changes were recorded because the highest proportion was found for beech in all plots. It can be seen that the mentioned increase caused a decreased proportion of fir in all plots whilst for the other tree species an increase was found. It is in accordance with the values of the total decrease of individual tree species during investigated period, which for an objective comparison was expressed as a percentage from number of trees of corresponding tree species in the initial stage of the research (Fig.1). Almost in all plots the highest decrease was recorded for fir on the contrary for beech where it was the lowest. An exception was found on Hrable PRP, where decrease of spruce was higher in comparison with other tree species. This plot is located in the Spiš region where already in the past a marked worsening of the health condition and/or spruce decline were found due to impact of air pollutants (Štefančík, Štefančík, 1993).

Above-mentioned development of tree species composition is remarkable especially for decrease of fir, which was according to our opinion caused by numerous factors. One of them

Table 2. Percentage of tree species composition on investigated PRP

Plot	Year	Tree species							Total
		spruce	fir	beech	pine	sycamore maple	birch	other	
Motyčky	1972	15.7	50.9	23.5	1.1	7.3	–	1.5	100
	2002	19.5	22.6	44.2	1.2	11.8	–	0.7	100
Korytnica 1	1968	24.3	25.3	46.2	–	3.3	–	0.9	100
	1998	29.8	17.5	48.2	–	3.8	–	0.7	100
Korytnica 3	1968	16.3	17.1	55.7	–	10.9	–	–	100
	1998	20.8	8.1	58.4	–	12.7	–	–	100
Hrable	1969	3.0	24.3	59.8	–	–	11.4	1.5	100
	1999	0.8	16.4	73.5	–	–	8.2	1.1	100

can be considered the fact that at the second half of the last century a marked air pollution occurred what resulted in worse health condition of forest in the whole Europe (Rehfuess, 1987). Effect of air pollutants was evident also in the area within the subjected stands (Maňkovská, 1997; Štefančík, Štefančík, 2001, 2002). It is known that especially fir belongs to the most sensitive tree species what was also confirmed by their increased mortality on our research plots. The changes related to fir decrease confirmed the known fact of its overall decline in forest stands during the last decades (Málek, 1983; Vladovič et al., 1998). Moreover, our results also correspond with knowledge published by Kantor, Pařík (1998), who have assessed changes in the tree species composition during a 35-year period of investigation in a 65-year mixed spruce, fir, pine, larch and beech stand that was not tended. The authors determined a considerable decrease in the fir proportion for 20 years from 28% to 17%. On the contrary, an increased proportion for beech and spruce by 5% and 9%, respectively, was found.

On the other hand, a considerable increase of beech proportion was found, which could be explained by the fact that the competitive ability of beech against other tree species is very strong under the given ecological condition. This fact is confirmed also by its height growth during the investigated period in comparison to spruce and fir (Fig.2). It can be seen, that in the initial stage of investigation in 1972 the fol-

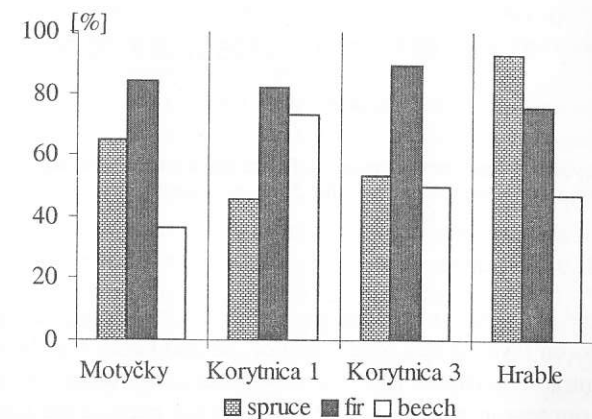


Fig. 1. Percentage of a total decrease (from number of trees) of individual tree species on investigated plots for a period of 30 years.

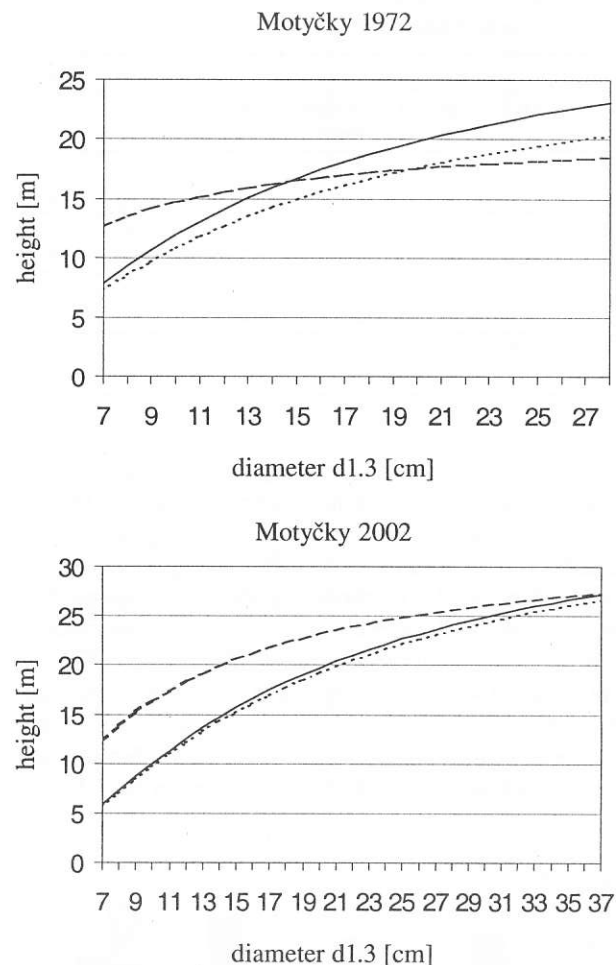


Fig. 2. The height curves for spruce, fir and beech on plot Motyčky in initial stage of the research and after 30 years. Legend: — spruce, ..... fir, - - - - - beech.

trend of development of height growth for individual tree species can be seen after 30 years also on investigated mixed spruce, fir and beech stands Motyčky and Korytnica. On the contrary, on Hrable PRP, the above-mentioned order was already found in the initial stage of our research as a result of the stand age because the investigation on this plot started at the stand age of 74 to 82 years. On other plots, already 30-year results have been available at this age of stand.

lowing order according to the height was registered: spruce, fir and beech. After 30 years the beech reached the upper crown layer, whilst fir together with spruce made up the medium crown layer.

Mentioned development has been caused by ecological demands of investigated tree species to be considered as different. Fir has the lowest demands on light and therefore it is frequently considered as more shaded tree species in comparison to beech. However, the demands of fir on light may also be changed due to dependence on other site (temperature, water regime, relative air moisture) and stand factors. It is known that fir tree species is very sensitive especially to temperature and moisture extremes from which it is partially protected inside the stand. On the other hand, beech is characterized by the better reaction to light especially in the older stands. Because of the mentioned fact, fir is very often overgrown by beech especially under the condition of its growth optimum. The above-mentioned

In this connection, the crown of tree species is very important parameter because it composes the stand canopy and/or their ability to take advantage of the given conditions within the competition between other tree species. Therefore, our consecutive research was focused on the mentioned parameter (size and/or crown width) which is very significant from the point of view of growth space utilization, especially within vertical profile of forest canopy.

Namely, crown size and/or the area of foliage together with other ecological factors influence the intensity of physiological processes (photosynthesis, respiration and so on) within the framework of vertical canopy structure, which results in biomass production of given forest stand (Masarovičová et al., 1996; Marek et al., 1997). Therefore, we compared a mean crown width of individual tree species (Fig. 3). It can be seen that differences between tree species were low and statistically insignificant ( $P > 0.05$ ). The crown size increased with the age of stand. It is known that crown size of trees can be influenced by silvicultural interventions, i.e. by removing undesirable individuals to release the crowns of remaining trees. However, on plots without interventions (as in our case), the crown size is made up due to competitive relations between tree species.

Owing to the fact that ecological conditions influence very markedly also the diameter growth, our interest was focused on crown width in relation to diameter increment of individual tree species, because it is considered as one of the most significant production parameters. By the method of correlation analysis, for beech a statistically significant relation ( $P < 0.01$ ) between crown width and mean annual diameter increment (correlation coefficient ranged from 0.795 to 0.864) was found in overall plots. For fir it was from 0.181 to 0.981, and in one plot the mentioned relation was found as insignificant ( $P > 0.05$ ). Similar results were found for spruce (correlation coefficient 0.453-0.819), where on two plots in Korytnica the investigated relation was also statistically insignificant ( $P > 0.05$ ). These results suggest a favourable growth for beech under the given conditions and its prevalence to spruce and fir within competitive relations. It is partially confirmed also by values presented in Fig. 4, where the highest mean annual diameter increment for spruce, contrary to lowest one for fir were found. The mentioned outcomes resulted in the fact that

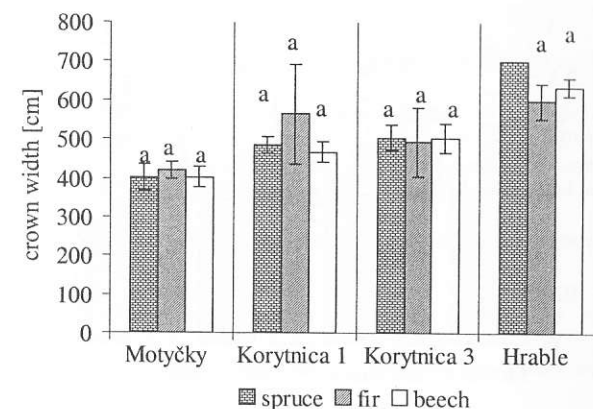


Fig. 3. Crown width of individual tree species on plots after 30-year research (average and standard error). Note: a – differences between the values with equal marks are statistically insignificant ( $P > 0.05$ ). Insufficient number of individuals for statistical elaboration were available for spruce on plot Hrable.

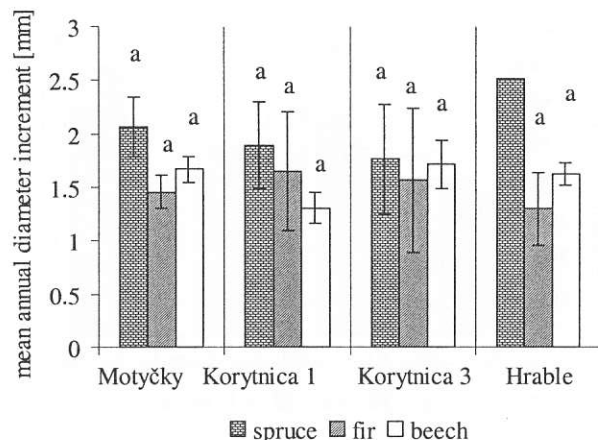


Fig. 4. Mean annual diameter increment of individual tree species on plots after 30-year research (average and standard error). Note: a – differences between the values with equal marks are statistically insignificant ( $P > 0.05$ ). Insufficient number of individuals for statistical elaboration were available for spruce on plot Hrable.

spruce mean diameter was found the highest in comparison with fir and beech on overall plots. Contrary of this, the mean diameter of beech was the lowest, however it had the highest diameter increment, although the differences between tree species were neither high nor statistically significant ( $P > 0.05$ ). It is due to the fact that larger trees have also a higher diameter increment in comparison with thinner trees (Šmelko et al., 1992).

## Conclusion

The aim of this paper was to ascertain and compare the fir growth in three mixed spruce, fir and beech stands in a 30-year period. The results showed, that in the initial stage of research fir was the second proportioned tree species on three plots and/or on one plot even the most frequent one. After 30 years the highest proportion for beech was found on overall plots. Due to mentioned increased beech proportion, fir proportion decreased in overall plots, whilst for the other tree species an increase was found. It is in accordance with the values of the total decrease, which was 76 to 89% for fir, 46-93% for spruce and the lowest was found for beech 36-73%.

On the contrary, beech was characterized by very strong competitive ability against other tree species under the given ecological conditions. This fact has been confirmed also by its height growth during the investigated period in comparison to spruce and fir. After 30 years, the beech reached the upper crown layer, whilst fir together with spruce made up the medium crown layer. As for mean crown width, differences between individual tree species were low and statistically insignificant ( $P > 0.05$ ), as well.

The crown width in relation to diameter increment of individual tree species was found the closest for beech in overall plots, as well as statistically significant ( $P < 0.01$ ). Fir and spruce showed lower values of correlation coefficient, and they were not always significant. The highest mean annual diameter increment was found for spruce and the lowest one for fir.

These results suggest a favourable growth for beech under the given conditions and its prevalence to spruce and fir within the competitive relations.

Translated by the author

## References

- Becker, M., Lévy, G., 1988: Á propos du dépérissement des forêts: Climat, sylviculture et vitalité de la sapinière Vosgienne. *Rev. forest. fr.*, 40, p. 345-358.
- Courtois, H., 1983: Die Tannenwurzel-Mykose, ihre Ursachen und Folgen. *Allg. Forstztg.*, 38, p. 211-213.
- Encke, B.G., 1982: Zum Stand der Tannenerkrankungen in Baden-Württemberg. *Allg. Forstztg.*, 37, p. 390-391.
- Kantor, P., Pařík, T., 1998: Production potential and ecological stability of mixed forest stands in uplands – I. A conifer stand with the admixture of beech at an acid site of the Křtiny training forest enterprise (in Czech). *Lesnictví-Forestry*, 44, p. 488-505.
- Korpeľ, Š., 1985: Stage and development of fir in Slovakia in relation to its dieback (in Slovak). *Acta Fac. Forestalis Zvolen*, 27, p. 79-104.
- Krammer, W., 1982: Das Tannensterben. *Forstarchiv*, 53, p. 128-132.
- Málek, J., 1983: The problem of silver fir ecology and its dieback (in Czech). *Studie ČSAV č.11/83*. Praha, Academia, 112 pp.
- Maňkiovská, B., 1997: Variation in sulphur and nitrogen foliar concentration of deciduous and conifers vegetation in Slovakia. *Water, Air, Soil Poll.*, 96, p. 329-345.
- Marek, M.V., Marková, I., Kalina, J., Janouš, D., 1997: Effect of Thinning on parameters of photosynthetic characteristics of Norway spruce canopy. I. Light penetration and photosynthesis. *Lesnictví-Forestry*, 43, p. 141-153.
- Masarovičová, E., Cicák, A., Štefančík, I., 1996: Ecophysiological, biochemical, anatomical and production characteristics of beech (*Fagus sylvatica* L.) leaves from regions with different degree of immission impact. *Ekológia (Bratislava)*, 15, p. 337-351.
- Rehfuess, K.E., 1987: Perceptions on Forest Disease in Central Europe. *Forestry*, 60, p. 1-11.
- Šmelko, Š., Wenk, G., Antanaitis, V., 1992: Growth, structure and production of the forest (in Slovak). Bratislava, Príroda, 342 pp.
- Štefančík, I., Štefančík, L., 2001: Assessment of tending effect on stand structure and stability in mixed stands of spruce, fir and beech on research plot Hrable. *J. For. Sci.*, 47, p. 1-14.
- Štefančík, I., Štefančík, L., 2002: Assessment of long-term tending in mixed stands of spruce, fir and beech on research plot Korytnica. *J. For. Sci.*, 48, p. 100-114.
- Štefančík, L., 1977: The cleanings and the thinnings in mixed stands of spruce, fir and beech (in Slovak). *Lesn. štúdie č. 25*, Bratislava, Príroda, 92 pp.
- Štefančík, L., Štefančík, I., 1993: Thinnings in pine-spruce pole-stage stands with advanced effect of immissions in the region of central Spiš (in Slovak). *Lesn. Čas.-Forestry Journal*, 39, p. 493-512.
- Vladovič, J. et al., 1998: Revaluation of target tree species composition with emphasis to utilization of natural regeneration (in Slovak). [Final report]. Zvolen, LVÚ: 53.

Received 3. 7. 2003

Štefančík I.: Rast a vývoj jedle bielej (*Abies alba* Mill.) v zmiešaných porastoch smreka, jedle a buka.

V príspevku hodnotíme rast jedle bielej na štyroch výskumných plochách Slovenska v zmiešaných smrekovo-jedľovo-bukových porastoch, kde sa nevykonávali žiadne zásahy za obdobie 30 rokov. Z výsledkov vidieť výrazný úbytok jedle, ktorý bol 76–89% z počtu stromov. Naopak, najväčšie zastúpenie dosiahol na všetkých plochách za sledované obdobie buk, ktorý sa dostal do hornej vrstvy, kým jedľa tvorila spolu so smrekom strednú vrstvu. Pokiaľ ide o priemernú šírku koruny, rozdiely medzi jednotlivými drevinami boli malé a štatisticky nevýznamné. Závislosť šírky koruny a hrúbkového prírastku jednotlivých drevín bola najtesnejšia u buka, a to na všetkých plochách, pričom bola aj štatisticky významná ( $P < 0.01$ ). Pri jedle a smrekovi sme zistili nižšie hodnoty korelačného koeficienta, pričom neboli vždy významné. Najvyšší priemerný ročný hrúbkový prírastok mal smrek a najmenší jedľa. Tieto výsledky naznačujú, že buk sa v daných ekologických podmienkach vyznačuje silnou konkurenčnou schopnosťou voči ostatným drevinám.