Changes in tree species composition, stand structure, qualitative and quantitative production of mixed spruce, fir and beech stand on Stará Píla research plot

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ABSTRACT: The paper is a contribution to the research on problems of thinnings in mixed (spruce-fir-beech) stands situated in the 5th forest altitudinal zone (beech with fir) in the central part of Slovakia. The research was carried out on two series of permanent research plots established in 1972. Each of the series consists of three partial plots where one plot was tended by free crown thinning in the framework of whole-area tending. On the second plot a non-whole-area tending was realised while the third ones were left without planned silvicultural treatment as controls. Dynamic changes in tree species composition, stand structure, qualitative and quantitative production including silvicultural analysis of seven thinning interventions were evaluated for a period of 29 years. A special attention was paid to development of future crop trees which are the main bearers of stand quality and quantity. The changes were compared with respect to differences between the plots with whole-area and non-whole-area long-term silvicultural treatment and the control plot (without treatments).

Keywords: thinnings; stand structure; crop trees; mixed stands; spruce – fir – beech

Mixed spruce, fir and beech stands are an important forest type of forest complexes in higher locations in the Alps and Carpathian Mountains. In Slovakia, the above-mentioned stands take up almost one fourth of the total forest area, i.e. more than 461,000 hectares mainly from the 4th (beech) to the 6th (fir with spruce and beech) forest altitudinal zone (Hladík 1996). The advantage of mixed stands in comparison with unmixed ones, especially from the aspect of their stability and/or resistance to injurious factors, has been known for a long time (Konôpka 1972; Vicena et al. 1979). Moreover, in connection with the expected influence of global climate change on forests, the outlines are often found by means of establishment and cultivation of mixed stands. Consequently, at present an effort is aimed at the maintenance and creation of as diverse as possible uneven-aged and spatial structure of forest stands. It can be achieved by the management of forests in correspondence with the principles of forest biodiversity maintenance and/or sustainable forest management. In connection with this, Leibundgut (1978) and Schütz (1994) stated that both diverse and individual mixture as well as more complicated stand structure could be created by early and intensive tending only, especially in commercial forests with first-rate wood production role of the forest and/or multifunctional forest management (Korpeľ 1997).

It is known that management of mixed stands requires more complicated silvicultural measures in comparison with unmixed stands. It can be stated that in other countries greater attention was paid to mixed spruce, fir and beech stands, for instance from the aspect of their establishment (Häberle 1997), competition (Pretzsch 1992a; Bachmann 1997), production and stability (Šmelko et al. 1992; Konôpka 1972; Kantor et al. 2002), growth model-

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ling and development of trees and stands by means of "growth simulators" (Pretzsch 1992b; Kahn, Pretzsch 1997).

More papers were also published about the tending of mixed spruce, fir and beech stands (Assmann 1961; Molotkov 1966; Hockenjos 1968; Leibundgut et al. 1971; Štefančík L. 1977, 1990; Paumer 1978; Hladík 1992; Štefančík, Štefančík 2001, 2002, 2003).

In Slovakia, research on the tending of mixed spruce, fir and beech stands started at the end of the 60's of the last century. For this reason four series of permanent research plots (17 partial plots) were established in localities of the Veľká Fatra Mts. and Low Tatra Mts. in the 5th (beech with fir) and 6th (fir with spruce and beech) forest altitudinal zone in natural areas of mixed spruce, fir and beech forests in Slovakia. The results of 30-year investigations in three series of the above-mentioned permanent research plots were published until now (Štefančík, Štefančík 2001, 2002, 2003). In this paper the changes in stand development on the last of the four above-mentioned series – permanent research plot Stará Píla are assessed. Likewise, it is a follow-up of the results of the first biometric measurement carried out on this plot and published in the past (Štefančík L. 1977).

The aim of this paper was to find out and assess the changes in tree species composition, stand structure, static stability, qualitative and quantitative production of mixed spruce, fir and beech stand on the Stará Píla permanent research plot (PRP) over a 29-year period of its tending.

MATERIALS AND METHODS

The mixed spruce, fir and beech stand on two series of Stará Píla PRP, established by Prof. Ing. L. Štefančík, DrSc., in the past for research on the problem of silviculture-production relations was chosen as an object of our research. These series of PRP are located in compartments 72 and 74 in the management-plan area Staré Hory, inside the zone of the Forest District Staré Hory, Branch Forest Enterprise Slovenská Ľupča. The plots were established in 1972 in the natural area of mixed spruce, fir and beech stands. Each of the two series of Stará Píla PRP consists of three partial plots (PP) where the trees are numbered and measurement points at breast height of 1.3 m are marked out. On each series of PRP one PP was left without treatment (control plot) and designated as "O". On the second one designated as "H" free crown thinning is applied (Štefančík L. 1984) and on the third one designated as "Hn" a non-whole-area tending is applied in the framework of biological rationalisation.

PP on the series of PRP I with the application of whole-area tending have an area of 0.04 ha and the plot with non-whole-area tending 0.08 ha in size consists of 30 circular growth areas (each of 7.065 m^2) with triangle arrangement and spacing of the centres of 6 m. The plots on the series of PRP II with whole-

Table 1. Basic characteristics of series I and II of Stará Píla permanent research plots (PRP)

Characteristic	PRP Stará Píla I	PRP Stará Píla II
Establishment of PRP (year)	1972	1972
Age of stand (years)	spruce 17, fir 17, beech 15	spruce 17, fir 19, beech 15
Geomorphologic unit	Nízke Tatry Mts.	Nízke Tatry Mts.
Exposition	W	E
Altitude (m)	690–720	690–720
Inclination (degree)	40	30–40
Parent rock	Mica schist slope deposits	Mica schist slope deposits
Soil unit	Cambisol	Cambisol
Forest altitudinal zone	5th fir – beech	5th fir – beech
Ecological series	A/B	B/C
Management complex	55	55
Management complex of forest types	511 fertile fir-beechwoods	511 fertile fir-beechwoods
Forest type group	*Fageto-Abietum (FA)* n.st.	*Fageto-Aceretum (FAc)* n.st.
Forest type	5204 fertile wood-sorrel beech firwoods n.st.	5402 male fern beech sycamorewoods n.st.
Average annual temperature (°C)	6.8	6.8
Average annual precipitation sum (mm/year)	1,100	1,100

area tending have an area of 0.06–0.08 ha and PP with non-whole-area tending 0.21 ha in size consists of 72 circular growth areas of the same size and arrangement as on the series of PRP I. We are aware of the very small area of research plots in comparison with standard one (0.25 hectare), but it was not possible to observe the instructions due to the given terrain configuration. The plots are isolated from each other and from another stand by a 10 m wide tree belt. The series have similar site conditions, but different exposition. More detailed characteristics of the research plots are presented in Table 1.

Since the establishment of the series of PRP, complex biometrical measurements of numbered trees have been carried out on all plots in 5-year intervals in accordance with standard methods that were developed for long-term research on thinnings (Štefančík L. 1977). In their framework, besides the quantitative parameters (breast height diameter, tree height, crown size at horizontal projection), the trees were also evaluated according to the silvicultural and commercial classification with orientation on the trees of selective quality (promising and crop trees). Since the establishment of PRP, seven biometrical measurements have been carried out and simultaneously thinning treatments have always been performed on the treated plots. From a rationalisation point of view, the method of promising trees and/or the method of crop trees on the plots with non-whole-area tending was applied. The first-rate results related to both diameter and height and/or qualitative structure on this PRP were published by Štefančík L. (1977) and Paumer (1978).

Experimental material was processed by common biometrical and statistical methods according to presented standard methods for research on thinnings (Štefančík L. 1977). Statistical significance of differences in arithmetical means of values was tested by Student's *t*-test.

At the end of 1993 and at the beginning of 1994, both series of PRP were afflicted by snowbreak. Consequently, an inventory after the mentioned event was carried out with the aim to find a decrease in the number of trees due to breaks and windthrows, as well as changes in tree species composition, stand structure and/or silviculture-production parameters. Ascertained data were processed together with the 6^{th} biometrical measurement carried out in 1998 (Štefančík I. 1999).

In this paper we assessed the first measurement carried out in 1974 (at stand age of 17–21 years) and the last measurement in 2003 (at stand age of 46–50 years) in order to compare changes in the investigated parameters on PP for the period of almost 30 years.

RESULTS AND DISCUSSION

Tree species composition

Percentage proportions of tree species according to the basal area (*G*) on Stará Píla PRP are presented in Fig. 1. At the initial stage of our research in 1974 the proportion of coniferous trees ranged from 50–83% on series I, while it amounted to 80–85% on series II. According to the tree species (except for plot I-O and II-H), the highest proportion was found on all plots for fir (55–69%), followed by spruce on series II (20–56%), beech on series I (17–50%) and (14–20%) on series II, and finally spruce on series I (2–16%) and sycamore maple (more than 1%).

After 29 years, the proportion of coniferous trees markedly decreased by 7–28% (except for plot I-H, where left unchanged). This decrease was caused especially by a reduction in the fir proportion to 4–36% on all plots. On the contrary, an increased proportion was found for broadleaved tree species, especially for beech by 7–26%, and the proportions of sycamore maple and other broadleaved trees (European mountain ash, whitebeam, goat willow) also increased on plots of series II.

A comparison of actual tree species composition with developmental objectives for the given site conditions according to Hančinský (1972) showed that the plots on series I slightly differed from the required composition by a higher fir, and especially beech proportion to the detriment of spruce and sycamore maple. On series II the actual tree composition corresponded to those developmental objectives, only the proportion of beech was higher to the detriment of Scotch elm.

The above-mentioned, almost 30-year changes were caused by various factors. Apart from silvicultural interventions, it is necessary to remind of the snow damage suffered on both series of PRP at the stand age of 36–40 years. The damage was caused by weather conditions in December 1993, especially by a heavy fall of snow during the last ten days of that year. The adverse snow effects resulted in top breakage of trees, windthrows and tree deformation, with prevailing broken trees in the lower part of the crown and trunk, which deteriorates wood raw material and threatens the forest hygiene on a large-scale (Korpeľ 1994).

The snow damage analysis on Stará Píla PRP showed that the plots on series II were damaged to a greater extent in comparison with the plots on

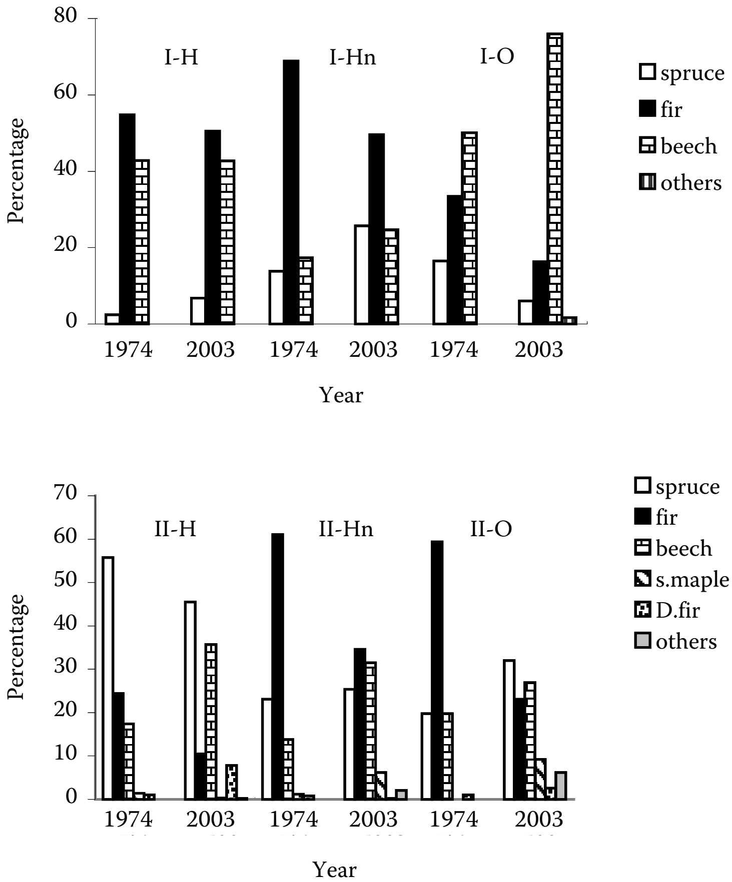


Fig. 1. Percentage proportions of tree species according to basal area on the series of Stará Píla PRP

series I, whilst spruce and Douglas fir were found to be the most injured tree species, contrary to beech with the lowest damage. In addition, another significant result was that damage on the plots without treatment was much greater than on the plots with systematic treatment (Štefančík I. 1999). The influence of global climate change could also be considered as another cause of tree species composition changes in favour of beech. Its impact is already visible and more notable effects are expected during the next decades (Minďáš, Škvarenina 2003). In the framework of the above-mentioned changes a vertical shift in the occurrence of some tree species towards a higher elevation is also assumed. Consequently, the occurrence of beech trees should be shifted to the detriment of the area covered by spruce towards higher locations. Our long-term (30 year) investigations carried out also in other PRP situated in mixed spruce, fir and beech stands have confirmed the above-mentioned trend so far.

In terms of fir decline or its increased dieback it can be stated that the above-mentioned phenomenon was found in numerous countries in other decades (Krammer 1982; Encke 1982; Málek 1983; Korpeľ 1985; Becker, Lévy 1988). The most frequent causes are climate change, especially drought and lack of precipitation, followed by abiotic factor damage as well as insect pests, fungal diseases and root decay. A lot of papers considered the widespread fir dieback to be due to air pollution (Encke 1982; Krammer 1982) but opinions related to inadequate management of forests with fir admixture were also presented (Schütt 1981; Hančinský 1983; Korpeľ 1985).

Stand structure

Stand structure was expressed by relative frequency according to the growth (tree) classes or by the percentage proportion of trees at the crown level of the stand (1st + 2nd growth class) and at the suppressed level of the stand (3rd to 5th growth class) on all plots. It must be stated that in the initial stage of our research (in 1974) the stands were in the stage of thicket, i.e. the trees were sorted into the three height classes (upper, intermediate, lower) according to relative height position.

The results presented in Figs. 2 and 3 show the differences between series I and II of PRP as well as between tree species at the beginning of our research. For spruce and fir a higher proportion was found at the suppressed level of the stand on series I of PRP, while at the crown level of the stand on series II of PRP. On the contrary, beech showed a minimal pro-

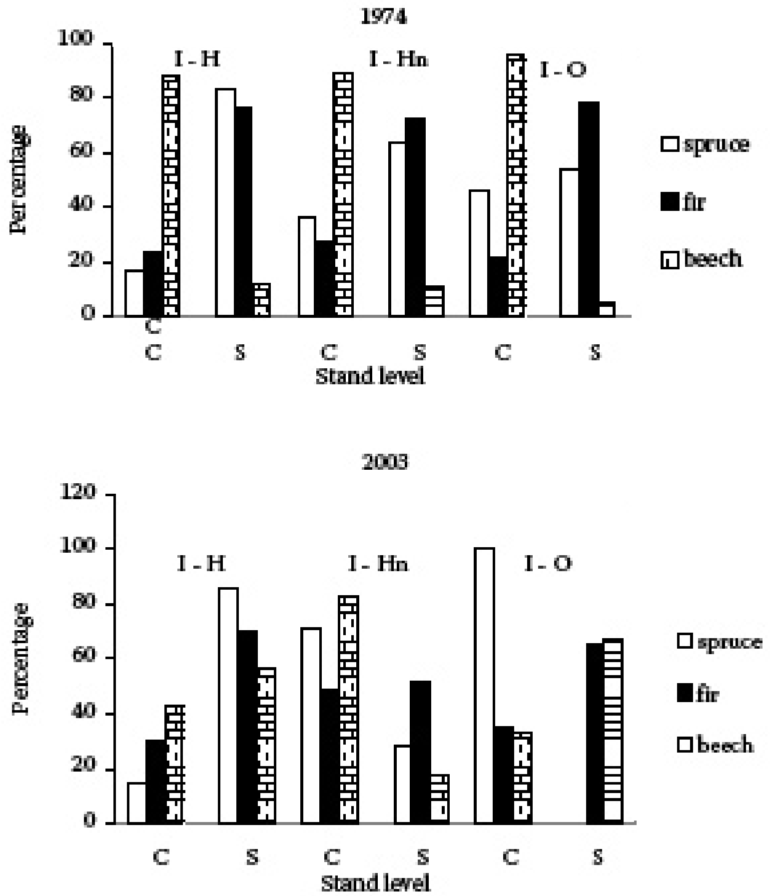


Fig. 2. Relative frequency of trees according to the level of the stand (C – crown level of the stand; S – suppressed level of the stand) on series I at the first measurement (in 1974) and at the 7th measurement (in 2003)

portion at the suppressed level of the stand on both series of PRP. These results correspond with those published by Paumer (1978) related to the height and diameter analysis of the above-mentioned plots at the stage of thicket. After the 29-year period the proportion of spruce on both series (except for plot

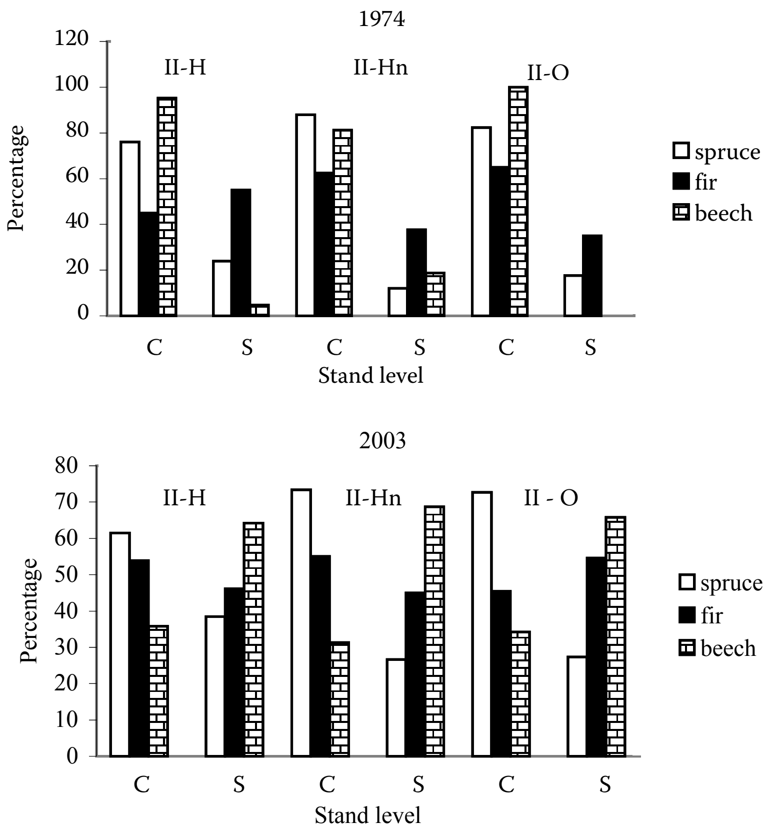


Fig. 3. Relative frequency of trees according to the level of the stand (C – crown level of the stand; S – suppressed level of the stand) on series II at the first measurement (in 1974) and at the 7th measurement (in 2003)

I-H) was higher (62–100%) at the crown level of the stand. As for fir, a higher proportion was found at the suppressed level of the stand (52–70%) on series I, while on series II it was more or less balanced. Beech had a higher proportion at the suppressed level of the stand (57–69%) on both series of PRP (except for plot I-Hn).

Described changes in tree (species) proportions at the given level of the stand after the period of investigations occurred due to treatments, height shift in the framework of stand development as well as the snowbreak disaster. The analysis of damage by snowbreak showed the highest proportion of spruce at the crown level of the stand on both series before the event. The second place was taken by fir, the proportion of which was higher at the crown level of the stand on series II in comparison with beech and vice-versa on series I (with the same validity for both treated and control plots). The proportion of tree species at the crown level of the mixed stand was changed after snowbreak. On treated plots, the proportion of spruce decreased by 15–22% at the crown level of the stand, while it was by 25% and 6% on control plots. As for fir, the proportion at the crown level of the stand was changed minimally on all plots. An increase in the proportion of beech at the crown level of the stand was small on treated plots and it was almost unchanged on control plots. It is to note that on less damaged series I the proportion of beech at the crown level of the stand was higher in comparison with series II (Štefančík I. 1999). These results correspond to knowledge published by Vicena et al. (1979) concerning the "consistence" effect of beech, especially in terms of its occurrence at the crown level of the stand.

From the aspect of long-term development of the investigated stands it can be stated that except for beech on both series of PRP and spruce and fir on series II, a small increase in the proportion of the above-mentioned tree species at the crown level of the stand was found after 30 years. Similar development was also found on other PRP in mixed spruce, fir and beech stands (Štefančík, Štefančík 2001, 2002, 2003).

Development of qualitative production by the method of crop trees

Table 2 documents the development of the trees of selective quality – TSQ (promising trees and/or crop trees) which are the objective of forest managers' silvicultural interest as main bearers of stand quality and quantity as well as from the aspect of ecological stability. We point out that the TSQ were selected on the basis of an elaborated criterion (Štefančík L. 1977) in the phase of pole-stage stand, so that an assessment of their development is considered as a little short from the time aspect. It can be seen that in the last measurement the number of TSQ was 380 and 268 individuals per hectare on the plots with whole-area tending (H), 1,038 and 864 individuals per hectare on the plots with non-whole-area tending (Hn), and 249 and 252 individuals per hectare on control plots, respectively. The proportion of

Table 2. Development of the trees of selective quality (future crop trees)

Plot	Age (years)	Number of trees (per 1 ha)	Basal area		Volume of timber to the top of 7 cm o.b.	
			(m^2/ha)	(% out of main stand)	(m^3/ha)	(% out of main stand)
I-H	31–33	516	5.76	25.2	28.36	37.0
	46–48	380	14.47	35.6	132.68	41.3
I-Hn	31–33	1,179	14.86	52.4	69.20	71.6
	46–48	1,038	43.21	70.4	414.62	75.6
I-O	41–43	249	6.39	18.0	48.83	23.8
	46–48	249	8.31	20.1	73.06	25.5
II-H	31–35	374	5.96	24.2	36.57	33.6
	46–50	268	12.51	36.4	126.40	42.4
II-Hn	31–35	1,317	14.70	53.4	77.52	64.3
	46–50	864	30.67	66.7	293.59	75.9
II-O	41–45	252	9.07	25.7	87.92	29.7
	46–50	252	12.20	27.6	124.71	32.0

H – plots with whole-area tending, Hn – plots with non-whole-area tending, O – plot without treatment (control)

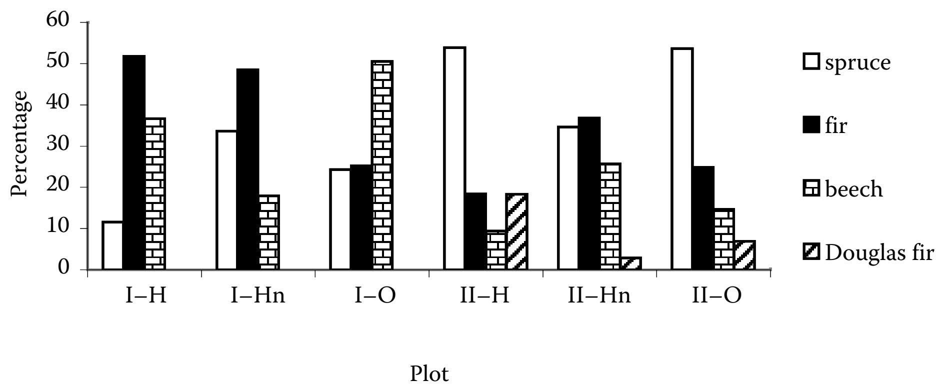


Fig. 4. Tree species composition of future crop trees after the 7th measurement at the stand age of 46–50 years

TSQ in the growing stock of the main stand ranged from 41% to 76% on tended plots, and between 26% and 32% on control plots. These values document unambiguously more favourable results on tended plots in comparison with the plots without treatment. A comparison of TSQ with the general model developed for spruce, fir and beech stands (Štefančík, Štefančík 2001), which indicates 200–260 crop trees per hectare for different variants, showed an adequate number of TSQ, even higher for non-whole-area plots. As for the tree species composition of TSQ (Fig. 4), the highest proportion was found on series I for fir (48–52%), except for the control plot where it was beech (51%). Except for plot II-Hn, spruce was the species with the highest proportion of 54% on series II. Beech showed the lowest proportion of TSQ out of the three principal species on all plots of series II (9–26%) as well as on plot I-Hn (18%). Only on two plots (I-H and I-O) the proportion of beech out of the TSQ was 37% and 51%, respectively, i.e. in accordance with the above-mentioned model developed for mixed stands, which indicates for beech a proportion of 30–50% depending on the variant.

Presented results correspond to our findings on other plots in mixed stands where the proportion of the TSQ out of the main stand growing stock ranged from 53–74% on tended plots of Korytnica PRP, 54–58% on Motyčky PRP and 47% on Hrable PRP. Similar results were found out on control plots of the above-mentioned series of PRP: 40–42%, 32% and 22%, respectively (Štefančík, Štefančík 2001, 2002, 2003).

As for the tree species composition of TSQ it can be stated that their actual state is a little different from the model on some plots or it did not achieve the assumed proportion of at least 30%. On the other hand, the number of TSQ is adequate for the given growth phase as well as in accordance with the model or it even exceeds it many times (plots with non-whole-area tending). In spite of the snow damage in the course of stand development, we assume that the production objective on investigated PRP will be achieved.

The cultivation of TSQ is important not only from silvicultural aspects but also from the aspect of stand stability because crop trees are the trees forming the core of the stand. It was already confirmed by research in the past that the most favourable results from the aspect of stand stability were achieved in stands with long-term cultivation by the method of crop trees (Konôpka 1992; Štefančík I. et al. 1999; Štefančík, Štefančík 2001, 2003). Growth para-meters of the crop trees of tended plots together (designated as H) and control plots (designated as O) are presented in Table 3. As it can be seen, however, only 15-year results showing almost all changes during this period were always significant on tended plots. In addition, very interesting seems to be the fact that practically no differences between the slenderness coefficients on control plots and tended ones were found. We explain it by the fact that after snowbreak a smaller number of crop trees remained on control plots in comparison with tended ones, and only the highest trees and the trees with largest diameter remained on control plots while on the other plots we were forced to select as crop trees (taking into account the quality criterion of course) also the trees of smaller size (diameter, height). It was also confirmed (Table 3) by the other parameters that were a little more favourable on control plots in comparison with tended ones. Owing to the stand age we assume in this respect that more favourable results should also be achieved in future by the method of systematic tending.

Development of quantitative production

Table 4 shows the number of trees per hectare (*N*) and basal area (*G*) in the initial stage of research (1974)

Table 3. Growth parameters of the trees of selective quality (future crop trees)

Plot	Tree species	Age (years)	Diameter $d_{1.3}$ (cm)		Height (m)		Crown width (m)		Crown length (m)		Ratio of crown length in total height of tree (%)		Slenderness coefficient	
			$\bar{x}$	$s_{\bar{x}}$%	$\bar{x}$	$s_{\bar{x}}$%	$\bar{x}$	$s_{\bar{x}}$%	$\bar{x}$	$s_{\bar{x}}$%	$\bar{x}$	$s_{\bar{x}}$%	$\bar{x}$	$s_{\bar{x}}$%
H	spruce	33	14.0	20.8	12.0	12.7	3.3	19.7	7.4	19.6	61.3	16.5	0.91	20.0
	fir	33–35	12.6	27.2	10.0	20.7	3.3	24.3	6.0	27.4	59.9	18.0	0.83	15.8
	beech	31	9.4	24.4	9.6	17.4	3.1	21.8	5.6	28.0	58.0	18.1	1.07	23.8
	Douglas fir^{+}	–	13.6	26.2	12.5	13.1	3.3	22.7	8.3	12.3	66.9	14.1	1.07	5.3
O	not selected^{++}	–	–	–	–	–	–	–	–	–	–	–	–	–
H	spruce	48	25.7**	17.0	20.8**	9.4	3.8*	23.5	10.8**	21.8	52.0**	18.2	0.82*	12.6
	fir	48–50	22.4**	19.9	19.0**	11.0	3.6^{N}	23.2	9.4**	26.9	49.1**	23.6	0.87^{N}	13.3
	beech	46	17.9**	16.4	17.2**	7.4	4.7**	15.6	9.2**	15.7	53.4*	13.3	0.98^{N}	11.7
	Douglas fir^{+}	–	27.7	29.2	20.0	19.5	4.5	14.2	12.0	38.6	57.4	24.6	0.75	13.4
O	spruce	48	28.2	13.6	21.4	9.1	4.8	16.5	11.4	13.9	53.3	11.2	0.77	9.0
	fir	48–50	22.9	14.4	19.8	12.6	3.8	16.0	8.9	20.3	44.7	12.7	0.87	4.4
	beech	46	18.3	14.3	16.9	9.2	4.9	19.5	9.4	19.3	55.6	15.4	0.93	13.5

H – plots with free crown thinning, O – plot without treatment (control), $\bar{x}$ – arithmetical mean, $s_{\bar{x}}$% – coefficient of variation
N – statistically insignificant difference ($P > 0.05$), * – statistically significant difference ($P < 0.05$), ** – statistically significant difference ($P < 0.01$)
Note: – insufficient number of individuals for statistical evaluation
$^{++}$ – trees of selective quality (future crop trees) on control plots were selected at the 6th measurement

as well as at the last measurement carried out in 2003. *N* was higher on plots of series I (22,743–45,943 trees per hectare) in comparison with series II (12,057–15,048 tress per hectare). On all plots, fir was the tree species with the highest representation followed by beech, spruce and other species (Douglas fir, sycamore maple, European mountain ash, goat willow). After the 29-year period of research *N* decreased to 2,500–3,856 trees per hectare on series I and to 1,785–2,631 trees per hectare on series II. The basic quantitative parameters found at the last measurement in 2003 are presented in Table 5.

It follows from the presented data that in most cases the values of *N*, *G*, volume of timber to the top of 7 cm o.b. (V_{7b}) were higher on plots of series I in comparison with series II. It was due to more intensive treatments on series II over the period of investigations as well as to a decrease in the number of trees by self-thinning (Table 6) and especially in consequence of the above-mentioned snowbreak, which caused greater damage on plots of series II. This development corresponds to total decrease on the given PRP recorded for the 29-year period of investigations (Table 7).

As for the comparison of obtained values with other experiments established in mixed spruce, fir and beech stands under comparable conditions (Motyčky, Hrable and Korytnica PRP) it can be stated that *N* was the highest on Stará Píla PRP because of its lowest stand age in comparison with the above-mentioned ones. For *G* the following values were found: 41.40 m^2/ha and 44.18 m^2/ha on control plots (without treatment) and for (V_{7b}) 286.8 m^3/ha and 389.2 m^3/ha. These values also very closely correspond to the stand age of 46–48 years, for

Table 4. Number of trees (*N*) and basal area (*G*) on the plots in 1974

Plot	Age (years)	Tree species	*N* total stand (trees/ha)	*N* treatment intensity (%)	*N* main stand (trees/ha)	*G* total stand (m^2/ha)	*G* treatment intensity (%)	*G* main stand (m^2/ha)
I-H	19	spruce	2,301	–	2,301	–	–	–
	19	fir	17,699	1.5	17,434	0.35	2.8	0.34
	17	beech	2,743	6.5	2,566	0.27	11.1	0.24
		total	22,743	1.9	22,301	0.62	6.5	0.58
I-Hn	19	spruce	1,792	2.6	1,745	0.15	86.7	0.02
	19	fir	41,887	6.5	39,151	0.76	36.8	0.48
	17	beech	2,264	12.5	1,981	0.19	47.4	0.10
		total	45,943	6.7	42,877	1.10	45.5	0.60
I-O	19	spruce	2,358	–	2,358	0.09	–	0.09
	19	fir	35,660	–	35,660	0.19	–	0.19
	17	beech	5,943	–	5,943	0.28	–	0.28
		total	43,961	–	43,961	0.56	–	0.56
II-H	19	spruce	5,519	–	5,519	0.75	–	0.75
	21	fir	5,802	–	5,802	0.33	–	0.33
	17	beech	2,453	–	2,453	0.24	–	0.24
		D. fir	802	–	802	0.01	–	0.01
		s. maple	425	–	425	0.02	–	0.02
		others	47	–	47	–	–	–
		total	15,048	–	15,048	1.35	–	1.35
II-Hn	19	spruce	2,181	0.9	2,161	0.39	–	0.39
	21	fir	7,917	4.2	7,583	1.04	11.5	0.92
	17	beech	2,495	–	2,495	0.24	–	0.24
		D. fir	295	–	295	0.01	–	0.01
		s. maple	1,081	1.9	1,061	0.02	–	0.02
		others	197	–	197	–	–	–
		total	14,166	2.6	13,792	1.70	7.1	1.58
II-O	19	spruce	3,191	–	3,191	0.28	–	0.28
	21	fir	6,170	–	6,170	0.85	–	0.85
	17	beech	1,915	–	1,915	0.29	–	0.29
		D. fir	426	–	426	0.01	–	0.01
		s. maple	142	–	142	–	–	–
		others	213	–	213	–	–	–
		total	12,057	–	12,057	1.43	–	1.43

For explanations see Table 2, *N* – number of trees per hectare, *G* – basal area per hectare

instance the value for *G* 46.27 m^2/ha and for (V_{7b}) 723.60 m^3/ha were found at the stand age of 104 to 112 years on Hrable PRP (Štefančík, Štefančík 2001). On Korytnica PRP *G* amounted to 43.73 and 45.35 m^2/ha and (V_{7b}) to 577.3 and 626.9 m^3/ha at the stand age of 80–88 years on control plots (Štefančík, Štefančík 2002). On Motyčky PRP the following values were found: *G* 38.13 m^2/ha and (V_{7b}) 423.2 m^3/ha (Štefančík, Štefančík 2003).

As for self-thinning expressed by the percentage decrease out of the total production (TP), the highest values were found on control plots (I-O and II-O): *N* 77.2 and 63.7%, and *G* 8.4 and 8.8%, finally (V_{7b}) 2.0 and 3.0%. The order of species according to the percentage decrease out of the TP was as follows: fir, spruce, other broadleaved tree species and beech. The same trend was already found on our above-mentioned research

Table 5. Number of trees (*N*), basal area (*G*) and their decrease on the plots in 2003

Plot	Age (years)	Tree species	*N* total stand (trees/ha)	*N* treatment (decrease) intensity (%)	*N* main stand (trees/ha)	*G* total stand (m^2/ha)	*G* treatment (decrease) intensity (%)	*G* main stand (m^2/ha)
I-H	48	spruce	269	41.6	157	3.41	18.4	2.78
	48	fir	1,456	13.9	1,254	21.35	4.0	20.50
	46	beech	1,434	9.4	1,299	18.68	7.2	17.34
		total	3,159	14.2	2,710	43.44	6.5	40.62
I-Hn	48	spruce	377	12.5	330	15.80	–	15.80
	48	fir	1,604	14.7	1,368	31.46	3.3	30.42
	46	beech	802	–	802	15.19	–	15.19
		total	2,783	10.2	2,500	62.45	1.7	61.41
I-O	48	spruce	75	33.3	50	2.51	2.0	2.46
	48	fir	498	15.1	423	6.99	3.6	6.74
	46	beech	3,731	10.7	3,333	32.34	2.6	31.50
		others	100	50.0	50	1.05	33.3	0.70
		total	4,404	12.4	3,856	42.89	3.5	41.40
II-H	48	spruce	502	9.2	456	16.05	2.5	15.64
	50	fir	163	7.4	151	3.64	1.0	3.61
	46	beech	1,178	8.9	1,073	13.55	9.3	12.29
		D. fir	58	–	58	2.68	–	2.68
		others	47	–	47	0.20	–	0.20
		total	1,948	8.4	1,785	36.12	4.7	34.42
II-Hn	48	spruce	373	21.2	294	12.56	7.2	11.66
	50	fir	825	4.7	786	16.09	0.9	15.95
	46	beech	1,317	4.5	1,258	15.43	6.2	14.47
		D. fir	19	–	19	0.08	–	0.08
		others	274	–	274	3.81	–	3.81
		total	2,808	6.3	2,631	47.97	4.2	45.97
II-O	48	spruce	448	12.1	394	14.93	5.3	14.14
	50	fir	394	–	394	10.20	–	10.20
	46	beech	735	–	735	11.90	–	11.90
		D. fir	36	–	36	1.15	–	1.15
		others	305	–	305	6.79	–	6.79
		total	1,918	2.8	1,864	44.97	1.8	44.18

For explanations see Table 2, *N* – number of trees per hectare, *G* – basal area per hectare

plots (Motyčky PRP and Korytnica PRP) as well as it was published by other authors (Štefančík, Štefančík 2002, 2003; Kantor et al. 2002; Klíma, Hubený 2002).

The evaluation of total decrease over 29 years according to *N*, *G* and V_{7b} (Table 7) did not show any differences between tended and control plots. It may be explained by different tending intensity on tended plots, and by different snow damage on plots. However, as for the order of tree species (according to the percentage of TP) unambiguously the highest reduction was found for fir again, followed by spruce and other broadleaved tree species. On the other hand, the lowest decrease was registered for beech.

Total production after 29 years of investigations on tended plots ranged from 56.01 to 72.67 m^2/ha (according to *G*) and from 385.1 to 571.4 m^3/ha (according to V_{7b} – Fig. 5). The values on control plots were as follows: 53.50– 75.45 m^2/ha and 335.60–562.40 m^3/ha, respectively. As for the trend of total production over

Table 6. A decrease of stand parameters by self-thinning over 29 years

Plot	Tree species	Decrease by self-thinning					
		number of trees		basal area		volume of timber to the top of 7 cm o.b.	
		(per ha)	(% of TP)	(m^2/ha)	(% of TP)	(m^3/ha)	(% of TP)
I-H	spruce	1,044	45.4	0.70	13.6	1.12	3.2
	fir	9,618	54.3	2.01	7.9	2.55	1.3
	beech	200	7.3	0.10	0.4	–	–
	total	10,862	47.8	2.81	5.1	3.67	1.0
I-Hn	spruce	660	36.8	0.05	0.3	–	–
	fir	24,811	59.2	1.60	4.3	3.59	1.2
	beech	95	4.2	–	–	–	–
	total	25,566	55.6	1.65	2.3	3.59	0.6
I-O	spruce	884	37.5	0.84	11.8	1.62	3.2
	fir	31,108	87.2	1.39	14.6	1.24	1.8
	beech	1,825	30.7	1.84	5.2	2.31	1.1
	others	100	57.1	0.42	33.3	1.42	21.7
	total	33,917	77.2	4.49	8.4	6.59	2.0
II-H	spruce	1,422	25.8	1.95	6.6	9.45	4.1
	fir	4,502	77.6	0.48	9.6	0.21	0.5
	beech	374	15.2	0.44	2.4	0.14	0.1
	D. fir	153	19.1	0.31	6.5	0.59	1.5
	others	177	37.5	0.03	3.0	–	–
	total	6,628	44.0	3.21	5.5	10.39	2.4
II-Hn	spruce	983	45.1	1.64	8.1	5.60	3.3
	fir	5,480	69.2	1.20	6.3	0.49	0.3
	beech	608	24.4	0.34	1.8	–	–
	D. fir	97	32.9	0.01	0.3	–	–
	others	669	52.3	0.05	1.1	–	–
	total	7,837	55.3	3.24	5.0	6.09	1.2
II-O	spruce	1,372	43.0	2.87	9.6	13.19	5.2
	fir	4,988	80.8	2.16	13.7	3.42	2.7
	beech	858	44.8	1.09	6.5	0.31	0.3
	D. fir	160	37.6	0.05	3.1	–	–
	others	304	85.6	0.23	2.7	–	–
	total	7,682	63.7	6.40	8.8	16.92	3.0

For explanations see Table 2, TP – total production

29 years, in the framework of tree species we found out the highest values for beech and Douglas fir and the lowest for fir, which corresponds to results on Motyčky PRP and partially also on Korytnica PRP (Štefančík, Štefančík 2002, 2003).

Silvicultural analysis of thinnings

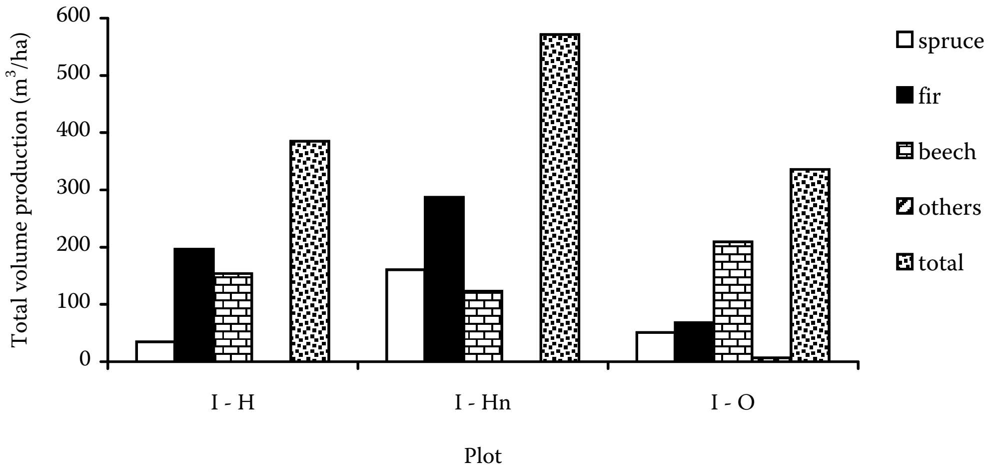
During the 29-year period of investigations, seven interventions in total were carried out on tended plots in an interval of 4 years between the 1st and 2nd treatment, and 5 years between the other ones. Silvicultural analysis showed that at the first thinning at the stand age of 17–21 years the thinning intensity (according to G) was 7.0%, on plot I-Hn even 46.0%, and the whole intervention was carried out at the crown level of the stand (its upper layer). The intensity of the 2nd treatment ranged in the interval of 7.5–9.7% with the proportion at the crown level of the stand 61.2–80%. Further decrease (windthrow),

Table 7. Total decrease of stand parameters over 29 years

Plot	Tree species	Number of trees		Basal area		Volume of timber to the top of 7 cm o.b.	
		(per ha)	(% of TP)	(m^2/ha)	(% of TP)	(m^3/ha)	(% of TP)
I-H	spruce	1,222	53.2	2.31	45.3	11.40	32.9
	fir	12,899	72.8	4.91	19.3	16.37	8.3
	beech	1,850	67.4	8.11	31.9	36.09	23.4
	others	44	100	0.06	100.0	–	–
	total	16,015	70.5	15.39	27.5	63.86	16.6
I-Hn	spruce	1,462	81.6	1.54	8.9	5.66	3.5
	fir	40,519	96.7	6.46	17.5	9.62	3.3
	beech	1,462	64.6	3.26	17.7	7.69	6.2
	total	43,443	94.5	11.26	15.5	22.97	4.0
I-O	spruce	1,183	50.2	4.62	65.2	27.49	53.8
	fir	31,471	88.2	2.78	29.2	8.01	11.7
	beech	2,516	42.3	4.13	11.6	11.27	5.4
	others	125	71.4	0.57	45.0	2.04	31.2
	total	35,295	80.3	12.10	22.6	48.81	14.6
II-H	spruce	3,531	64.0	13.92	47.1	80.06	34.6
	fir	4,879	84.1	1.40	28.0	5.43	13.6
	beech	1,367	55.7	6.28	33.8	25.66	23.7
	D. fir	352	43.9	1.98	42.6	10.98	27.6
	others	329	69.7	0.90	81.4	4.55	84.9
	total	10,458	69.5	24.48	41.6	126.68	29.8
II-Hn	spruce	1,887	86.5	8.58	42.5	53.29	31.7
	fir	7,131	90.1	3.09	16.2	7.11	4.6
	beech	1,237	49.6	4.22	22.6	19.38	16.1
	D. fir	276	93.6	2.31	96.5	20.46	99.3
	others	1,005	78.6	0.82	17.8	3.16	11.2
	total	11,536	81.4	19.02	29.3	103.40	21.0
II-O	spruce	2,286	71.6	15.70	52.6	116.42	45.50
	fir	5,718	92.6	5.60	35.4	25.80	20.4
	beech	1,360	71.0	4.91	29.2	19.66	18.8
	D. fir	178	41.8	0.61	34.7	5.54	32.9
	others	483	100	1.44	17.5	5.77	9.8
	total	10,025	83.1	28.26	39.0	173.19	30.8

For explanations see Table 6

negative stem and sanitary selection accounted for the remaining percentage. The third treatment was carried out at the intensity of 1.1–4.2%, being focused on positive selection at the crown level of the stand, with the proportion of 66.7–100% and further decrease (windthrows). At the 4th intervention the treatment intensity ranged from 8.1 to 23.5%. At this intervention, i.e. at the stand age of 31–35 years, all kinds of selection were already applied, namely positive selection at the crown level of the stand (75–94%), positive selection at the suppressed level of the stand (1.1–18.5%), negative stem selection (0.5–4.5%) and negative sanitary selection (less than 4%). Of course, at this treatment further decrease (windthrows) was also recorded, its proportion was less than 4.4% out of the total treatment. The 5th treatment was characterised by the intensity of 2.2–9.0%. As for its location in the stand profile, an increased proportion of positive selection at the suppressed level of the stand (7.0–38.5%) was



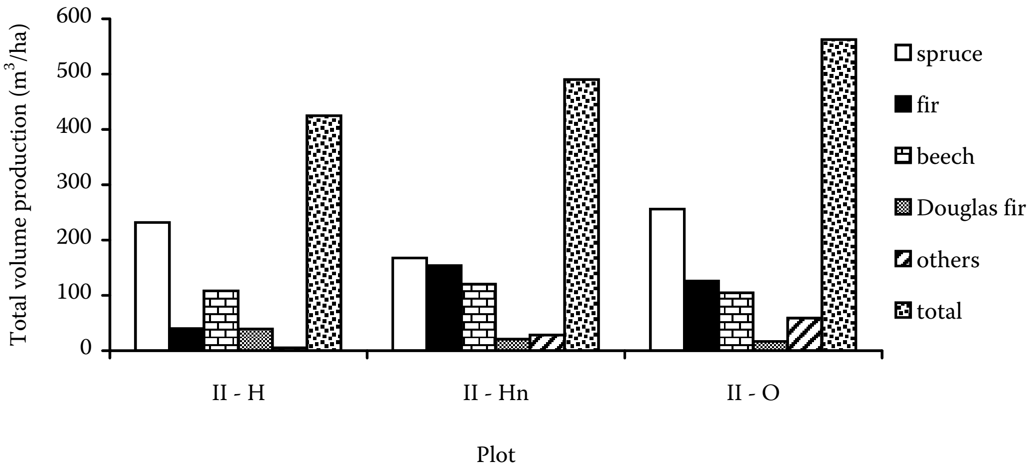


Fig. 5. Total volume production on the series of Stará Píla PRP over 29 years of investigation

found and on plot I-H also a negative stem selection (19.2%) in comparison with previous treatments. The highest proportion was taken by positive selection at the crown level of the stand (42.3–90.4%). A relatively higher proportion of further decrease due to windthrows and stem breaks (9.6–34.6%) was registered on series II and even 100% on plot I-Hn due to felling by the practice. To analyse the

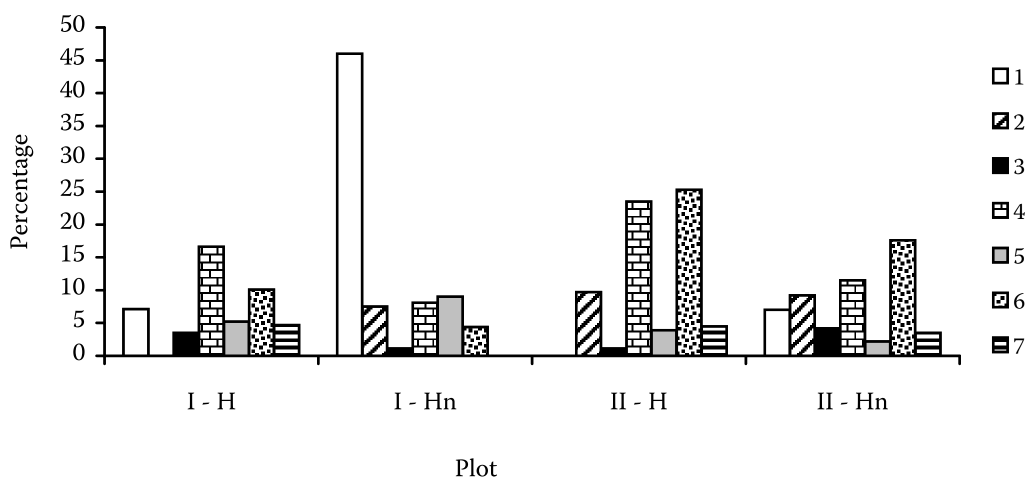


Fig. 6. Thinning intensity (according to basal area) based on the order of treatments on tended plots of Stará Píla PRP

6th treatment we have to take into account the fact that a year after the 5th treatment both research series were damaged by snow. It resulted in a decrease in the number of trees, expressed by treatment intensity 4.4–25.3%, as well as in a higher proportion of further decrease (26.7–100%). Nevertheless, in spite of different damage on individual plots (Štefančík I. 1999), it was necessary to realise an intervention on some plots, but its intensity was significantly lower. Due to the treatment a positive intervention at the crown level of the stand accounted for 3.9–27.2% out of the total decrease followed by negative stem selection (3.5–37.2%), but positive selection at the suppressed level of the stand was carried out only on plot I-H (proportion 8.9%). The analysis of the 7th treatment showed partial regeneration after snowbreak and thinning intensity ranged from 3.5% to 4.7%. The highest proportion was found for positive intervention at the crown level of the stand (85.7–100%), followed by positive intervention at the suppressed level of the stand (10–11%).

It can be concluded that thinning intensity (expressed by G) on all plots (except for the 1st treatment on plot I-Hn) and except for the 4th and 6th treatment did not exceed 10% (Fig. 6), which should be considered as a low intensity. Actual research outcomes especially for deciduous trees recommend more intensive treatments mainly at the young stand age in order to ensure the static stability of stands (Vicena et al. 1979; Štefančík I., Kamenský 1999). From silvicultural aspects very important knowledge is that static stability against snow can be influenced the most markedly in initial growth stages (Pařez 1972; Vicena et al. 1979), namely by intensive treatments up to the stand age of 20–30 years (Jurča, Chroust 1973; Slodičák 1987). These opinions are in accordance with the statement of Molotkov (1966). He recommended the thinning intensity of the first treatment performed in mixed spruce, fir and beech stands to be 15–30% of the growing stock and subsequent interventions with the intensity of 10–20%.

Our results showed lower values especially at the first three interventions, when the treatment intensity (according to V_{7b}) did not exceed 5% on Stará Píla PRP and later it ranged from 0.5% to 22.4%. These results are also in accordance with recommendations by Korpeľ (1995), who suggested that across the thinning methods the variants of crown thinning with positive selection (method of candidate or crop trees) should be consistently carried out. As for the thinning intensity, the cited author states that thinning intensity lower than 10% of the growing stock with thinning interval of 5 years results in the equalisation of stand structure and one-layer constitution of stand within a strong horizontal canopy, as well as in a decline or dieback of admixed tree species, especially fir.

Based on the presented results found also on other research plots (Korytnica, Motyčky, Hrable PRP) established in mixed spruce, fir and beech stands it can be stated that one, more intensive treatment (15–25%) could be enough for a period from 7 to 10 years, as for the thinning intensity and interval. It is also in accordance with our previous results (Štefančík, Štefančík 2002, 2003).

CONCLUSION

The evaluation of 29-year changes in the tree species composition, stand structure and stability, qualitative and quantitative production of approximately 50-year mixed spruce, fir and beech stand, located in the 5th forest altitudinal zone on a fertile site, brought the following results:

– In the initial stage in 1974, the proportion of coniferous trees ranged from 50 to 83% on plots of series I, and from 80 to 85% on plots of series II. According to the tree species on all plots (except for plots I-O and II-H) the highest proportion was found for fir (55–69%), followed by spruce (20–56%) on series II, beech (17–50%) on series I, beech (14–20%) on series II and finally spruce (2–16%) on series I and sycamore maple (more than 1%). After 29 years, a marked decrease in the proportion of coniferous trees by 7–28% was found on all plots (except for plot I-H, which remained unchanged). This decrease was caused especially by fir whose proportion decreased by 4–36% on all plots. On the contrary, an increased proportion of broadleaved tree species, especially of beech by 7–26%, and on plots of series II also an increased proportion of sycamore maple and other broadleaved tree species (European mountain ash, whitebeam, goat willow) were recorded.
– In the initial stage, the proportion of spruce and fir at the suppressed level of the stand on plots of series I was higher, contrary to series II. The proportion of beech was found minimal at the suppressed level of the stand on both series. After the 29-year period the proportion of spruce was higher at the crown level of the stand (62–100%) on both series (except for plot I-H), a higher proportion of fir was found at the suppressed level of the stand (52–70%) on series I, while on series II it was more or less balanced. As for beech, a higher proportion was found at the suppressed

level of the stand (57–69%) on all plots (except for I-Hn).

– The number of the trees of selective quality (TSQ), i.e. promising trees and future crop trees, was 380 and 268 individuals per hectare on plots with whole-area tending (H), 1,038 and 864 individuals per hectare on plots with non-whole-area tending (Hn), and 249 and 252 individuals per hectare on control plots (O). The proportion of the TSQ out of the main stand growing stock ranged from 41 to 76% on tended plots, and between 26 and 32% on control plots. As for the tree species composition of TSQ, the highest proportion was found for fir (48–52%) on series I, and for beech (51%) on the control plot. On series II, spruce was the species with the highest representation (54%) except for plot II-Hn. On all plots of series II, beech accounted for the lowest proportion out of the TSQ of the three principal species (9–26%), and also on plot I-Hn 18%.
– In the initial stage of research the number of trees (*N*) was higher on series I (22,743–45,943 individuals per hectare) in comparison with series II (12,057–15,048). Fir was found as the most frequent species, followed by beech, spruce and finally by other tree species (Douglas fir, sycamore maple, European mountain ash, goat willow) on all plots. After 29 years *N* decreased to 2,500–3,856 individuals per hectare on series I, and to 1,785–2,631 individuals per hectare on series II. The following values of *G* were found: 41.40 and 44.18 m^2/ha on control plots and 34.42–61.41 m^2/ha on tended plots, and those of V_{7b} 286.8 and 389.2 m^3/ha and 297.9–548.44 m^3/ha, respectively.
– As for the decrease in *N* caused by self-thinning expressed by the percentage of the decrease out of total production (TP), the highest values were found on control plots (I-O and II-O). According to *N*, *G* and V_{7b} it was 77.2% and 63.7%, 8.4% and 8.8%, 2.0% and 3.0%, respectively. When expressed according to the percentage decrease out of TP the following order of species was found: fir, spruce, other broadleaved tree species and finally beech.
– The assessment of total decrease according to *N*, *G* and V_{7b} over 29 years unambiguously showed the highest reduction in fir (according to the percentage of TP), followed by spruce together with other broadleaved tree species. The lowest decrease was found for beech.
– Total production during 29 years of investigation on tended plots ranged from 56.01 m^2/ha to 72.67 m^2/ha (according to *G*) and 385.1 m^3/ha to 571.4 m^3/ha (according to V_{7b}). The values on control plots were as follows: 53.50 m^2/ha and 75.45 m^2/ha, and 335.6 m^3/ha and 562.40 m^3/ha, respectively. As for a trend of total production of particular tree species over 29 years, we found the highest values for beech and Douglas fir and the lowest for fir.
– The silvicultural analysis showed that the treatment intensity (according to *G*) on all plots (except for plot I-Hn at the 1st treatment), as well as at the 4th and 6th treatment did not exceed 10%. The treatment intensity at the 4th treatment ranged from 8.1% to 23.5%. Before the 6th measurement, both series of PRP were affected by snow damage, which resulted in a decrease in the number of trees, and treatment intensity (4.4–25.3%). The most intensive treatment was carried out by positive selection at the crown level of the stand and the lowest by negative stem selection or sanitary selection.

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Zmeny drevinového zloženia, porastovej výstavby, kvalitatívnej a kvantitatívnej produkcie zmiešaného smrekovo-jedľovo-bukového porastu na výskumnej ploche Stará Píla

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ABSTRAKT: Práca je príspevkom k výskumu problematiky prebierok v zmiešaných (smrekovo-jedľovo-bukových) porastoch 5. lesného vegetačného stupňa v oblasti stredného Slovenska. Výskum sa uskutočnil na dvoch sériách trvalých výskumných plôch založených v roku 1972. Na každej zo sérií sú tri čiastkové plochy, pričom na jednej sa aplikovala úrovňová voľná prebierka v rámci celoplošnej výchovy. Na druhej ploche sa uskutočnila neceloplošná výchova, resp. tretia plocha sa ponechala bez úmyselného zásahu ako kontrolná. Vyhodnotili sa dynamické zmeny drevinového zloženia, porastovej štruktúry, kvantitatívnej a kvalitatívnej produkcie vrátane pestovnej analýzy siedmich zásahov za obdobie 29 rokov. Osobitná pozornosť sa venovala vývoju budúcich cieľových stromov, ktoré sú hlavnými nositeľmi kvalitatívnej i kvantitatívnej produkcie porastu. Zistené zmeny sa porovnali z hľadiska rozdielov medzi dlhodobo celoplošne i neceloplošne vychovávanými plochami a kontrolnou plochou (bez zásahu).

Kľúčové slová: prebierky; porastová štruktúra; cieľové stromy; zmiešané porasty; smrek – jedľa – buk

Cieľom práce bolo zistiť a zhodnotiť zmeny v drevinovom zložení, porastovej štruktúre, statickej stabilite, kvalitatívnej a kvantitatívnej produkcii zmiešaného smrekovo-jedľovo-bukového porastu na výskumnej ploche Stará Píla za 29-ročné obdobie výchovy.

Objektom výskumu boli dve série trvalých výskumných plôch (TVP) Stará Píla, ktoré boli založené v minulosti pre výskum problematiky pestovno-produkčných vzťahov v zmiešaných smrekovo-jedľovo-bukových porastoch. Série TVP sa nachádzajú v dielcoch 72 a 74, Lesný hospodársky celok (LHC) Staré Hory, lesný závod Slovenská Ľupča, lesná správa Staré Hory. Plochy boli založené v roku 1972 v prirodzenej oblasti jedľovo-smrekovo-bukových porastov v obvode bývalého lesného závodu Banská Bystrica.

Každá z dvoch sérií TVP sa skladá z troch čiastkových plôch, na ktorých sú stromy očíslované s označením meriska hrúbky vo výške 1,3 m. V rámci každej série TVP je jedna čiastková plocha bez zásahu (kontrolná) označená ako „O“, na druhej čiastkovej ploche označenej ako „H“ sa sleduje úrovňová voľná prebierka (Štefančík 1984) a na tretej označenej ako „Hn“ sa v rámci biologickej racionalizácie výchovy porastov aplikuje neceloplošná výchova. Podrobnú charakteristiku výskumných plôch uvádzame v tab. 1.

Na každej sérii TVP sa od ich založenia vykonávajú kompletné biometrické merania očíslovaných stromov v päťročných intervaloch v zmysle štandardných metodík pre výskum prebierok. V rámci nich sa okrem kvantitatívnych parametrov (hrúbka $d_{1,3}$, výška stromov a nasadenia koruny, šírka korún) klasifikovali stromy aj podľa pestovnej a hospodárskej klasifikácie so zameraním na stromy výberovej kvality (nádejné a cieľové stromy). Od založenia výskumných plôch sa vykonalo sedem biometrických meraní vrátane zásahu na vychovávaných plochách. Z hľadiska fytotechniky sa aplikuje metóda nádejných stromov, resp. na plochách s neceloplošnou výchovou metóda cieľových stromov.

V príspevku sme zhodnotili prvé biometrické meranie, ktoré sa vykonalo v roku 1974 (vo veku porastu 17–21 rokov), a posledné meranie v roku 2003 (vo veku porastu 46–50 rokov), aby sme porovnali zmeny v sledovaných parametroch na jednotlivých plochách za obdobie takmer 30 rokov.

Vyhodnotenie 29-ročných zmien v drevinovom zložení, porastovej štruktúre, kvalitatívnej a kvantitatívnej produkcie približne 50-ročného zmiešaného smrekovo-jedľovo-bukového porastu v 5. lesnom vegetačnom stupni na živnom stanovišti prinieslo nasledujúce výsledky:

Pri východiskovom stave v roku 1974 sa zastúpenie ihličnatých drevín pohybovalo na plochách série I v rozpätí od 50 % do 83 %, kým na plochách série II to bolo od 80 % do 85 %. Z jednotlivých drevín bola na všetkých plochách (okrem plôch I-O a II-H) najviac zastúpená jedľa (55–69 %), potom smrek na sérii

II (20–56 %), buk na sérii I (17–50 %), buk na sérii II (14–20 %) a nakoniec smrek na sérii I (2–16 %), resp. javor horský (vyše 1 %). Po 29 rokoch sa zastúpenie ihličnatých drevín výrazne znížilo o 7–28 % (okrem plochy I-H, kde sa nezmenilo). Bolo to spôsobené najmä úbytkom jedle, ktorej podiel klesol na všetkých plochách o 4–36 %. Naopak zvýšil sa podiel listnatých drevín, najmä buka, o 7–26 %, ale na plochách série II vzrástlo tiež zastúpenie javora horského a ostatných listnatých drevín (jarabina, mukyňa, rakyta).

Pri východiskovom stave smrek aj jedľa na sérii I mali prevahu v podúrovni, kým na sérii II v porastovej úrovni. Naopak buk mal na obidvoch sériách iba minimálne zastúpenie v podúrovni. Po 29 rokoch bol smrek na obidvoch sériách (okrem plochy I-H) zastúpený viacej v porastovej úrovni (62–100 %), jedľa bola na sérii I viac zastúpená v podúrovni (52 až 70 %), kým na sérii II bolo jej zastúpenie viac-menej vyrovnané. Pokiaľ ide o buk, ten bol na obidvoch sériách (okrem plochy I-Hn) početnejší v podúrovni (57–69 %).

Počet SVK bol na plochách s celoplošnou výchovou (H) 380 ks/ha a 268 ks/ha, na plochách s neceloplošnou výchovou (Hn) 1 038 ks/ha a 864 ks/ha, resp. na kontrolných plochách (O) 249 ks/ha a 252 ks/ha. Podiel SVK na zásobe hlavného porastu sa pohyboval od 41 % do 76 % na zasahovaných plochách, kým na kontrolných plochách bol iba 26 % a 32 %. Čo sa týka drevinového zloženia SVK, najvyšší podiel tvorila na sérii I jedľa (48–52 %) okrem kontrolnej plochy, kde to bol buk (51 %). Na plochách série II to bol najviac zastúpený smrek (okrem plochy II-Hn) s podielom 54 %. Buk tvoril najnižší podiel z SVK troch hlavných drevín na všetkých plochách série II (9–26 %), resp. aj na ploche I-Hn (18 %).

Na začiatku výskumu bol na plochách série I vyšší počet stromov *N* (22 743 až 45 943 ks/ha) v porovnaní so sériou II (12 057 až 15 048 ks/ha). Na všetkých plochách bola najpočetnejšou drevinou jedľa, potom nasledovali buk, smrek a napokon ostatné dreviny (duglaska, javor, jarabina, rakyta). Po 29-ročnom období klesol *N* na sérii I na 2 500 až 3 856 ks/ha, resp. na sérii II na 1 785 až 2 631 ks/ha. Hodnota *G* bola na kontrolných plochách (bez zásahu) 41,40 m^2/ha a 44,18 m^2/ha, na zasahovaných plochách to bolo 34,42 m^2/ha až 61,41 m^2/ha, resp. hodnota V_{7b} bola 286,8 m^3/ha a 389,2 m^3/ha na kontrolných plochách a 297,9 m^3/ha až 548,44 m^3/ha na zasahovaných plochách.

Čo sa týka samoprerieďovania, ktoré sme vyjadrili percentom úbytku z celkovej produkcie (CP), najvyššie hodnoty sme zistili podľa očakávania na kontrolných plochách (I-O a II-O). Podľa *N* to činilo 77,2 % a 63,7 %, podľa *G* 8,4 a 8,8 %, resp. podľa V_{7b} 2,0 a 3,0 %. Pri vyjadrení podľa percenta úbytku z celkovej produkcie bolo poradie podľa drevín nasledujúce: jedľa, smrek, ostatné listnáče a buk.

Hodnotenie celkového úbytku podľa *N*, *G*, a V_{7b} za obdobie 29-rokov podľa poradia drevín (podľa percenta z CP) ukázalo jednoznačne najväčší úbytok pri jedli. Smrek bol druhý v poradí spolu s ostatnými listnáčmi a najmenší úbytok sa zaznamenal pri buku.

Celková produkcia po 29-rokoch sledovania sa pohybovala od 56,01 m^2/ha do 72,67 m^2/ha na zasahovaných plochách (podľa *G*) a 385,1 až 571,4 m^3/ha (podľa V_{7b}). Na kontrolných plochách to činilo 53,5 a 75,45 m^2/ha, resp. 335,6 a 562,4 m^3/ha. Trend nárastu celkovej produkcie pre jednotlivé dreviny ukázal najvyššie hodnoty pre buk a duglasku a najnižšie pre jedľu.

Pestovná analýza prebierok ukázala, že sila zásahu (vyjadrená podľa *G*) na všetkých plochách (s výnimkou 1. zásahu na ploche I-Hn) a okrem 4. a 6. zásahu neprevýšila 10 %. Pri 4. zásahu sa sila pohybovala od 8,1 % do 23,5 %. Pri 6. zásahu boli obidve série plôch poškodené snehom, čo sa významne prejavilo na úbytku stromov, resp. na vyjadrenej sile zásahu (4,4–25,3 %). Najväčší podiel pri všetkých zásahoch pripadol na pozitívny úrovňový výber a najmenší na negatívny tvarový výber, resp. zdravotný výber.

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